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## AMERICAN WELDING SOCIETY

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# JOURNAL OF THE AMERICAN WELDING SOCIETY

VOLUME X | SEPTEMBER, 1931 | NUMBER 9

## Fall Meeting Program

There is published in this issue a number of the papers to be presented at the Fall Meeting of the AMERICAN WELDING SOCIETY.

These papers represent thousands of dollars in investigational work, as well as considerable time on the part of the individual authors and companies who have set forth their experience for the benefit of the members of the Society and the industry at large.

The success of the Fall Meeting depends to a considerable extent on the discussion—written and oral—of these papers. Every member of the Society who is in a position to add to the knowledge of the various welding subjects covered in these papers is in duty bound to do so.

It was impossible to print all of the papers in this issue. The remainder will be printed in the October and November numbers. These additional papers are as follows:

*Structural Steel Report.* A review of the work of this Committee. The investigations undertaken by it and the results of tests of 1395 program specimens made up by 39 fabricating shops and tested at 24 laboratories, will be presented by the Executive Committee of the Structural Steel Welding Committee. The report itself occupies a book of several hundred pages. (Advance copies are now available at $1.00 per copy at office of the Society.)

*The Yale University Group of Welded Buildings,* by G. D. FISH, Consulting Engineer. This paper will describe 4 all-welded buildings at Yale University, including, the new Administration Building for the Sheffield Scientific School; a 7-story quadrangle of dormitories, and the hospital addition.

*Welding of Galvanized Steel,* by H. F. REINHARD, J. B. Colt Company. The author sets forth some of the latest methods of successful Oxy-acetylene welding of galvanized steel.

*Fatigue Properties of Welds,* by R. A. WEINMAN, General Electric Company. The results of a series of experiments on welds made during the past two years by the atomic hydrogen process using a large variety of steels and welding rods will be summarized.

*Welding of Copper and Brass Piping,* by H. V. INSKEEP, Development Section, Engineering Department, Linde Air Products Co. This paper will review some new developments and technique in the applications of gas welding of brass and copper piping from the smallest to the largest sizes.

*Welding of Piping in New York Hospital—Cornell Medical Clinic,* by H. SAMUELSEN, Almirall & Co. This paper describes the methods of fabrication used in variety of piping up to 24 inches in diameter for gas, water, steam and other purposes.

*Semi-Automatic Gas Welding,* by T. W. GREENE, Engineer, Development Section, Engineering Dept., Linde Air Products Co. The author explains in detail some of the latest developments in Semi-Automatic welding of pipe and other important applications of welding. Paper is to be accompanied by a two-reel motion picture.

*Underwater Cutting,* by C. KANDEL, Craftsweld Equipment Corp. Mr. Kandel will give an illustrated lecture on the latest developments of underwater cutting including diving equipment and underwater cutting. This lecture will be discussed by Commander Edward Ellesberg who has had extensive experience on important underwater cutting projects.

The Fall Meeting program includes a special outing which has been arranged for Thursday afternoon, September 22, consisting of a trip to Pemberton by boat. This trip will include shore dinner and sports and the return trip will be made by boat in the evening.

Special program has been provided for the ladies. The exposition will be opened at 12 noon on Monday and every day thereafter during the Congress at the same time and will close at 10:00 p. m. every night except Thursday, when it will close at 6:00 p. m.

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## Good Welding Depends on Good Welders

*Reprinted from Aug. 8th issue of Electrical World.*

Not long ago the engineering department of a large Eastern operating utility decided to utilize electrically welded construction wherever possible in the erection of steelwork. This company having no welders in its employ, it sought to hire some. Those applying for work were of varying degrees of experience and skill. To each were given test specimens to fabricate; then examinations and tests were made of the welds. All the commonly accepted rules for visual evaluation of weld quality were applied, and physical-strength determinations were checked against these observations.

At intervals, after intermediate training, these observations and tests were repeated with the same men. The results were amazing, for it was soon conclusively demonstrated that while the appearance of the weld was not an infallible index of quality, the man who made it was a definite assurance of predictable results. Under training the men improved, but in general it was evident that no examination or non-destructive test was so good an assurance of weld quality as the answer to this question, "Who welded this?" Men who, without much previous training or experience, were poor welders seldom became good ones, but good ones became better. The personal element proved most important.

As a result, in erecting important, new, virtually all-welded structures, this organization adopted the plan of using only those welders who had shown consistently good results in shop tests. No elaborate field examinations of welds were made, and the whole structure was allowed to rely on the personal element. The men, fully understanding the situation, turned out work which no amount of supervision, insistence, field examination or tests could of themselves have yielded. Upon the personal element many welding jobs may depend. Good welders should be at a premium in the years of the welded age which is upon us.

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## Authors of Fall Meeting Papers

There follows a brief biographical sketch of some of the authors of the Fall Meeting papers.

R. F. HELMKAMP, author of the paper on "Automatic Gas Cutting," has been identified with the welding industry since 1916. In 1917 he was made welding foreman of a large department in the Curtiss Airplane Company's plant, Buffalo, making welded ailerons, rudders, elevators, stabilizers, and other welded components. Following military service overseas he became a service welder with the Air Reduction Sales Company, working in the Eastern railroad shops. During this period he became an expert operator of Airco-D-B cutting machines. He is now specialist of the Air Reduction Applied Engineering Department on mechanical welding and cutting machines. Mr. Helmkamp, who is the designer of the present Oxygraph central control system for multiple torch operation, both mechanical and electric, including automatic lighting of the torches, has given much study to stack cutting and multiple torch operation for production work.

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P. J. HORGAN, author of the paper on "The Engineer, The Welder and The Foundryman," is Chairman of the River Works Welding Committee of the General Electric Company and has been actively identified with the

development of welding at the Lynn plant. He graduated from the Wakefield, Mass., High School in 1904; attended the Lowell Institute and graduated from the General Electric Apprentice course in 1909. He has also been associated with the United Shoe Machinery Company as mechanical engineer. During the last seven years he has been foreman of the Experimental Drafting room. His assignments with the General Electric Company for five years were as contact man between Engineering Department and machine shop on Steam Turbines and assistant to the General Superintendent of Foundries and Pattern Shops coordinating designs to produce quality castings at costs commensurate with expected production.

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CHAS. H. JENNINGS, author of the paper on "The Relief of Welding Strains by Annealing," graduated from the Mechanical Engineering Department of Iowa State College with a degree of Bachelor of Science in M. E. He has been connected with the Westinghouse Electric and Manufacturing Company as a graduate student, as an engineer in the Mechanics Division and finally in their Research Laboratories. His efforts have been confined during the past few years to the fundamental investigation of the physical properties of arc welds. He is a member of the American Society of Mechanical Engineers, the AMERICAN WELDING SOCIETY and Chairman of the Welding Society's Committee for the Revision of the Bulletin on Fundamentals of Electric Arc Welding.

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CHARLES KANDEL, who will lecture on "Underwater Cutting" was graduated from Columbia University in 1911 with the degree of C. E. He is a member of the AS.C.E. and has been identified with the welding industry since 1917 having served as Construction Engineer for the International Oxygen Company in various parts of the United States, France and Switzerland. He was General Sales Manager for the American Oxygen Service Company from 1922 to 1925; General Sales Manager for the International Oxygen Company for their Newark, Pittsburgh and Toledo plants in 1926 and since 1927 has been President and General Manager of the Craftsweld Equipment Corp. Has contributed numerous articles on welding and has served as Secretary of the New York Section of the AMERICAN WELDING SOCIETY in 1929 and is a member of the Oxy-Acetylene Committee of the International Acetylene Association.

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FRED J. MAEURER, author of the paper on "Welded Pipings and Fittings in Heating Installations," has been identified with the Oxy-Acetylene welding industry since 1907. In that year he became connected with the Brooklyn Navy Yard where he served successfully in the operation of the first complete Davis-Bournonville oxyacetylene generating and compressing installation. He became connected with the Davis-Bournonville Company in 1909 and was active in the installation and operation of generating and compressing plants in the oil industry. He superintended welding departments of Davis-Bournonville Co. from 1912 to 1922 when they merged with the Air Reduction Sales Co. He has thus had 24 years of continuous service with the oxyacetylene industry; serving as welder, foreman, superintendent, sales engineer, Installation engineer, and specialist in the plumbing and heating field.

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FRANK P. MCKIBBEN, author of the paper on "Welding Solves Another Problem," graduated from Massachusetts Institute of Technology; and for 32 years taught theory of structural design, first at that institution and then at Lehigh University and Union College. In 1926 he resigned his position at Union, and also as city engineer of Schenectady, to devote his time to his engineering practice which he had carried on for many years.

At present, consulting engineer of the General Electric Co. in connection with welding of steel structures, and of the city of Rochester, N. Y., where he is in charge of design and construction of two large bridges.

Mr. McKibben has been connected with the welding of many structures among which the following are the principal:

Power House, Hotel Chalfont-Haddon Hall, Atlantic City, N. J.; Court House, Montgomery County, Norristown, Penna.; Office Building, Edison Electric Illuminating Co., Boston, Mass.; Office Building, Dallas Power & Light Co., Dallas, Texas; Office Building, three separate projects, Du-Pont Co., Wilmington, Del. Several factory buildings for General Electric Co.

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W. T. OBER, author of the paper on "Resistance Welding of Metal Fabric," graduated from the General Electric Engineering School in 1916 and attended the Lowell Institute in Cambridge. He was employed by General Electric Co. at Lynn as draftsman until 1917 at which time he entered the employ of the Thomson-Gibb Electric Welding Company, Lynn, as draftsman. He later became designer, experimental and development engineer, sales engineer and still later, Assistant Sales Manager, which position he now holds.

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E. R. TORGLER, author of the paper on "Four Problems Encountered in Flash-Welding Mild Steel," graduated from Case School of Applied Science in 1922 with B.S. Degree in Metallurgy. He received additional training under Prof. Boylston, after which he spent five years on the coast of Mexico doing examination and development work on gold and silver properties. He was engaged in similar work in the Black Hills of South Dakota making a survey and examination of gold-silver-lead property and 100 ton flotation mill. For the last two and one-half years he has been Metallurgist for the S. R. Dresser Manufacturing Company. He received his Master's Degree from Case School in 1931.

IRA THOMAS HOOK, author of the paper on "Large Welded Everdur Pressure Vessels," was born in Elkridge, Maryland, 1887. Was skilled machinist before graduating from University of Michigan in 1913 in civil engineering. In experimental engineering with the General Motors Corporation and the American Brass Company, since then with 1½ years in the U. S. Army and 3 years teaching strength of materials at Yale University in the interim. Has broken up enough material to build a battleship to find out what it is good for. Welding copper alloys since 1925. Member A.S.M.E., A.I.M.E., A.W.S., Sigma Xi, Major U.S.R.

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## Structural Steel Report

The report of the research investigations of the Structural Steel Welding Committee of the American Bureau of Welding is now available at Society headquarters—$1.00 per copy. This report constitutes a complete record of the activities to date of the committee, which was organized in 1926 for the purpose of "obtaining reliable information upon which to base safe unit working stresses in the designing of welded structures."

After reviewing all of the test data in the literature available at that time (see summary published in the American Welding Society Journal, November, 1927), the committee concluded that a comprehensive series of tests should be made before final recommendations were promulgated.

An investigation was therefore undertaken, the principal objects of which, after some modifications during the progress of the work, were the determinations of:

1. Safe design values under static loading for various types of fusion welded joints as commercially welded in structural steel fabricating shops.
2. The degree of uniformity of the strength of welded joints that may be expected from such shops throughout the country.

In order that the results of the investigation would be thoroughly representative of commercial practice, a large number of shops were invited to participate. To insure the maximum uniformity of procedure in the conduct of the tests, comprehensive instructions were prepared covering all details from the selection of the welders to the preparation of test reports by the cooperating laboratories.

The final program, as carried out and reported herein, included the welding and testing of 1098 specimens in connection with the qualification of the welders and 1395 specimens in connection with the investigation proper—the latter involving 55 elemental forms of joint in 169 sizes.

The participants in the investigation included three steel mills, 39 fabricating shops, 61 welders, 18 inspectors and 24 testing laboratories. The work was distributed over the central and eastern portions of the United States. A Canadian laboratory provided pilot or preliminary information based on the testing of 342 specimens welded in three Canadian shops. About five years have been spent on the entire investigation.

# Welded Pipe and Fittings in Heating Installations

**Efficiency—Economy—Weight Saving—Fabrication of Joints—Fabrication of Headers—Welding Fittings—Spacing and Tacking—Expansion and Contraction—Adaptability and Portability of Oxyacetylene Apparatus—Welding Piping in the Home—Illustrations.**

*By* **FRED J. MAEURER**

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by Fred J. Maeurer, Air Reduction Sales Company, New York, Applied Engineering Department.

DURING the past few years rapid strides have been made in the welding of pipe in heating installations, superseding the older method of screwed fittings. This has progressed so far that at present an all-welded heating installation is accepted by architects, building owners, heating contractors and plumbers and steamfitters as standard practice.

The paramount reason for this attitude is that journeymen plumbers and steamfitters have finally become convinced that they must learn pipe welding or compete with another trade. They now find it possible to do this efficiently and economically in their local vocational schools, which have been supplied with special pipe welding courses, lectures, charts, pipe templets and engineering assistance and supervision.

As an indication of this trend, there are now approximately 175 vocational schools in the United States teaching pipe welding to plumbers and steamfitters. The demand for more classes is so great school officials predict that many more will undoubtedly be started within the next year. The registrations in these schools run from 30 men to 900 men, and the classes are from 5 to 30 men to a group.

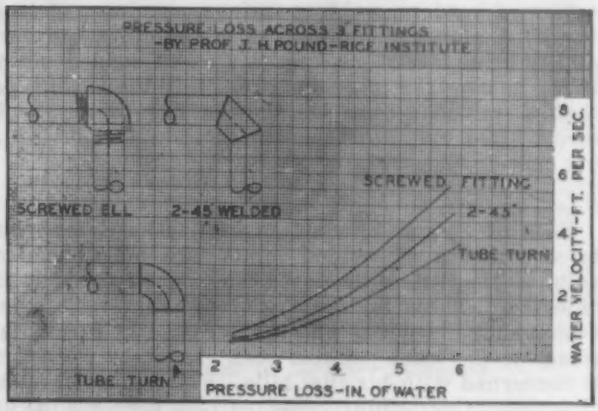



**Fig. 1—Reduction of Friction Loss in Welded Fittings**

As a result of this vocational school training of plumbers and steamfitters, architects now specify welded joints, and heating contractors find themselves in the enviable position of being able to bid on welded installations. Their journeymen know how to weld pipe, and they no longer find it necessary to

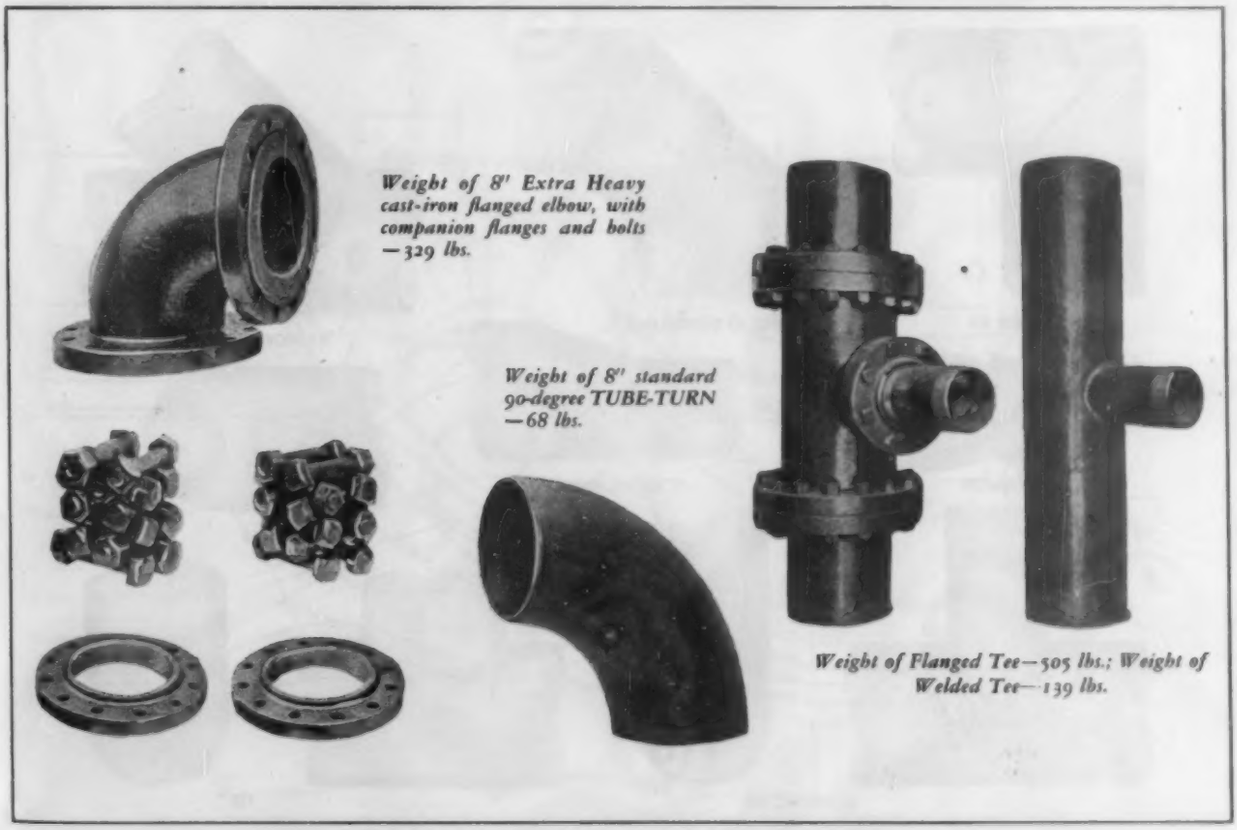

*Weight of 8" Extra Heavy cast-iron flanged elbow, with companion flanges and bolts —329 lbs.*
*Weight of 8" standard 90-degree TUBE-TURN —68 lbs.*
*Weight of Flanged Tee—505 lbs.; Weight of Welded Tee—139 lbs.*

**Fig. 2—Comparative Weights of Welding and Screwed Fittings**

trust their welding on heating installations to men who have had little or no training in this type of work.

There are many reasons why a welded piping installation is now considered standard practice, superseding the old screw-fitted method. The outstanding reason is that it is BETTER. Other reasons are efficiency, economy and weight saving. In considering these, we will also discuss fabrication of joints, fabrication of headers, welding fittings, spacing and tacking, expansion and contraction, adaptability and portability of oxyacetylene apparatus, and welded piping in the home. The foregoing are not all the advantages that a welded piping installation has over the old screw fitted one, but they are some of the outstanding ones.

### Efficiency

Ease of flow and reduction of friction losses, due to smoothness of welded joints, are of economical value as they affect the cost of delivering steam to its objective. These factors are of vital interest to the owner of the building who is interested in furnishing steam at the least possible cost. In other words, he is concerned with his fuel bills. Fig. 1 shows results of a test to determine pressure loss across 3-in. fittings. It will be noted from the curves that the tube turn had approximately 38 per cent less pressure loss than the screwed ell. In addition, welds in pipe are as strong as the pipe itself and eliminate maintenance and upkeep costs.

### Economy

The overall economy that is effected by a pipe welded installation over the old method of screwed fittings is made up of several factors which would require much space to describe fully. They start at the pipe mill and actually extend beyond the finished installation itself.

Some of the outstanding economies are:

(a) Beveled pipe costs less than threaded pipe. Less joints as a rule are used in a welded installation than where the old method of screwed fittings is employed.

Fig. 4—3-Inch Pipe Fittings Fabricated by Oxyacetylene Process

(b) Insulation costs (asbestos lagging and covering) are much less because of smoothness of outside of welded pipe. This also reduces heat loss. Unevenness is created by the old method of bulky screwed fittings which call for special insulation shapes.

(c) A welded joint is a permanent installation that practically eliminates maintenance costs.

(d) No scrap pipe or expensive fittings are left over. Even if screwed fittings can be returned for credit, it costs money to acquire and stock them, in clerical work, insurance, handling, losses, etc.

(e) No expensive and heavy pipe threading machinery has to be moved from plant to job, and then from floor to floor as the work progresses.

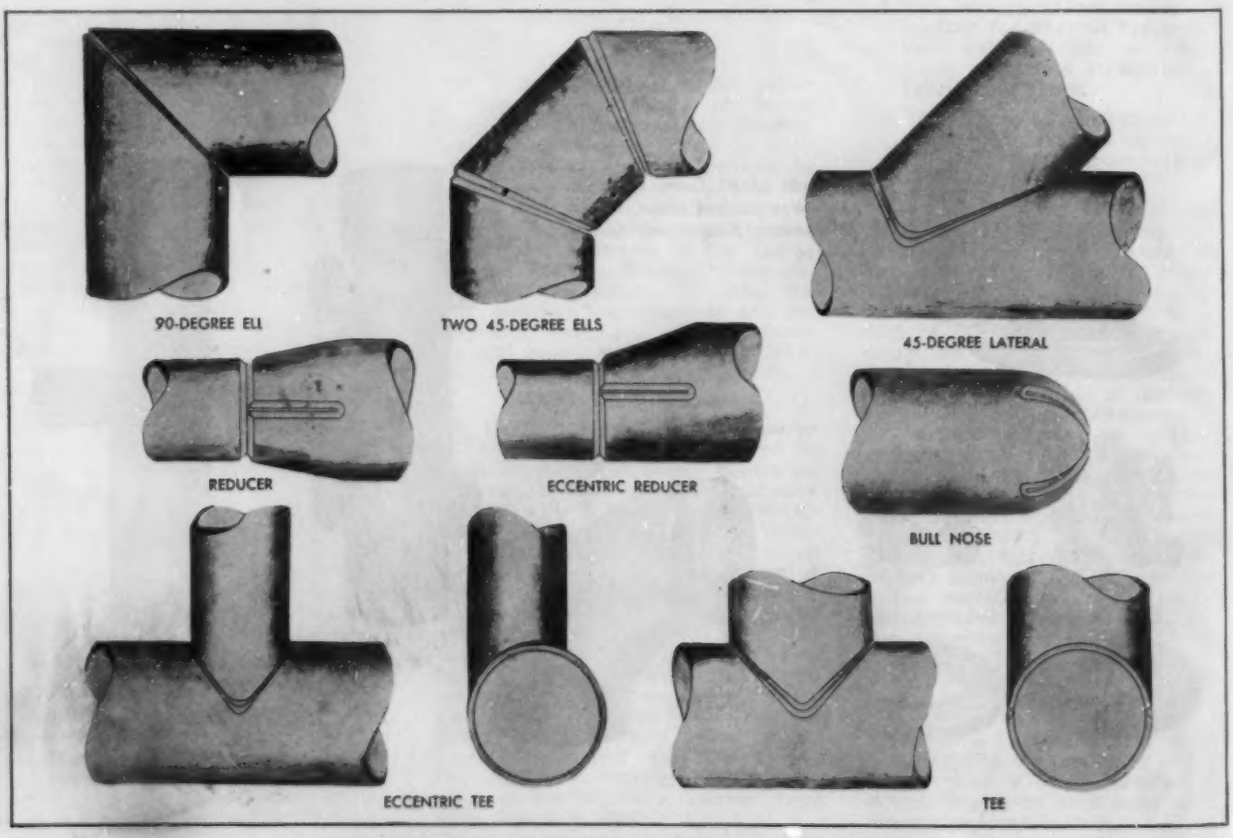



Fig. 3—Pipe Fittings Fabricated on the Job by Oxyacetylene Process

(f) All stock lengths of pipe which are obtainable at lower cost, can be used. It is not necessary to order standard lengths, as with threaded pipe.

(g) The greatest potential economy in heating installations will come through the use of thin wall pipe, weighing considerably less than that now being widely employed on welded transmission lines. This is inevitable within the next few years.

### Weight Saving

The weight of a heating installation should receive serious consideration because of the important part it plays in the drawing up of plans for the building in which it is to be installed.

Architects recognize that a welded piping installation means a big saving in weight, which is advantageous, especially in multi-story buildings. It enables them to draw up building plans that are more flexible and economical than they would be if for screwed fitting installations.

With decreased weight they get an installation that is as strong as the pipe itself because the welded joint is in no way weakened by threading operations required for a screwed fitting. As a matter of fact, a weld in a pipe is not rightly a joint but is in reality a continuation of the pipe itself; it adds little or no weight to the pipe.

The reduction in the weight of a welded installation makes itself evident not only in the welds, but in the fittings, headers, hangers, and in many other ways. Two good examples of the remarkable savings in weight effected through the use of welding fittings are shown in Fig. 2. In the case of the 8-in. elbow a tube turn saves 261 lb., or 79 per cent. The weight of the welded Tee is 366 lb. less than that of the flanged Tee, representing a saving of 72 per cent. Each and every weld effects a saving in weight regardless of where it is applied. Economies in weight mean savings both in material and in labor charges for handling.

John Zink of Baltimore recently made public some figures on the reduction of weight due to welding on a typical pipe installation in Washington, D. C. This saving was 14,400 lb., which means that there were seven (7) tons less material to be handled and hoisted into place.

The figures are as follows:

| | | |
|---|---|---|
| Total weight of boiler header piping originally designed for flanged steel fittings.. | 17,700 lb. | |
| Total weight of welded boiler header piping installed ..... | | 10,500 lb. |
| Total weight of flanged steel fittings including bolts but no auxiliary flanges..... | 6,500 lb. | |
| Total weight of Tube Turns and pipe used for intersection welds to replace flanged fittings ..... | | 1,050 lb. |
| Total weight of steel flanges necessary for installation ..... | 3,700 lb. | |
| Total weight of welding neck flanges installed and taking full advantage of flanges that welding eliminated..... | | 1,950 lb. |
| | 27,900 lb. | 13,500 lb. |

### Fabrication of Joints—Templets

An outstanding advantage in installing welded pipe is that, with the aid of the oxyacetylene cutting and welding torch many types of fittings can be fabricated on the job. This obviates the necessity of carrying a large fitting stock. Furthermore, some of these fabricated fittings can be made only by the oxyacetylene process. Several examples of such fittings are illustrated in Fig. 3. Fig. 4 shows an assortment of 3-in. fittings which have been fabricated with the oxyacetylene cutting torch and are ready for welding.

By using proved simplified pipe templets, as illus-

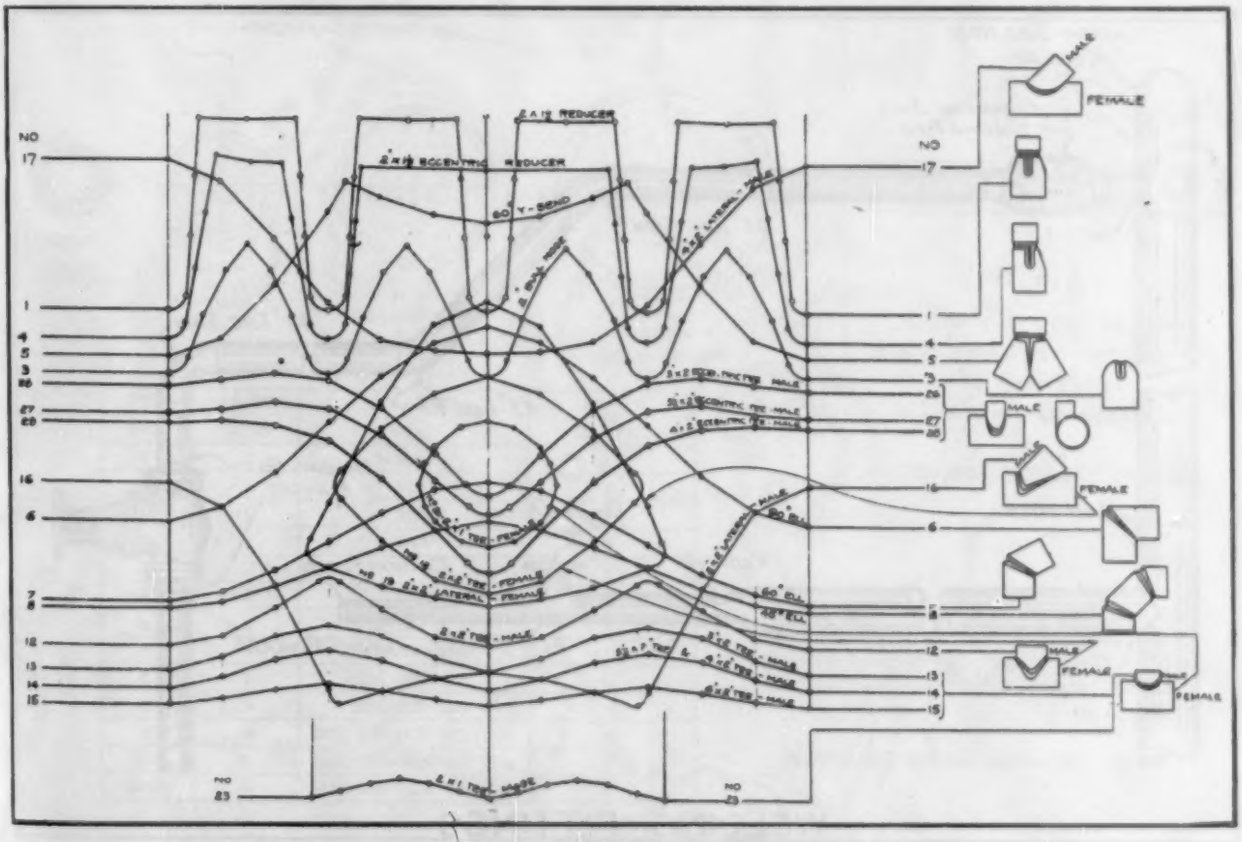



Fig. 5—2-Inch Pipe Cutting Curves

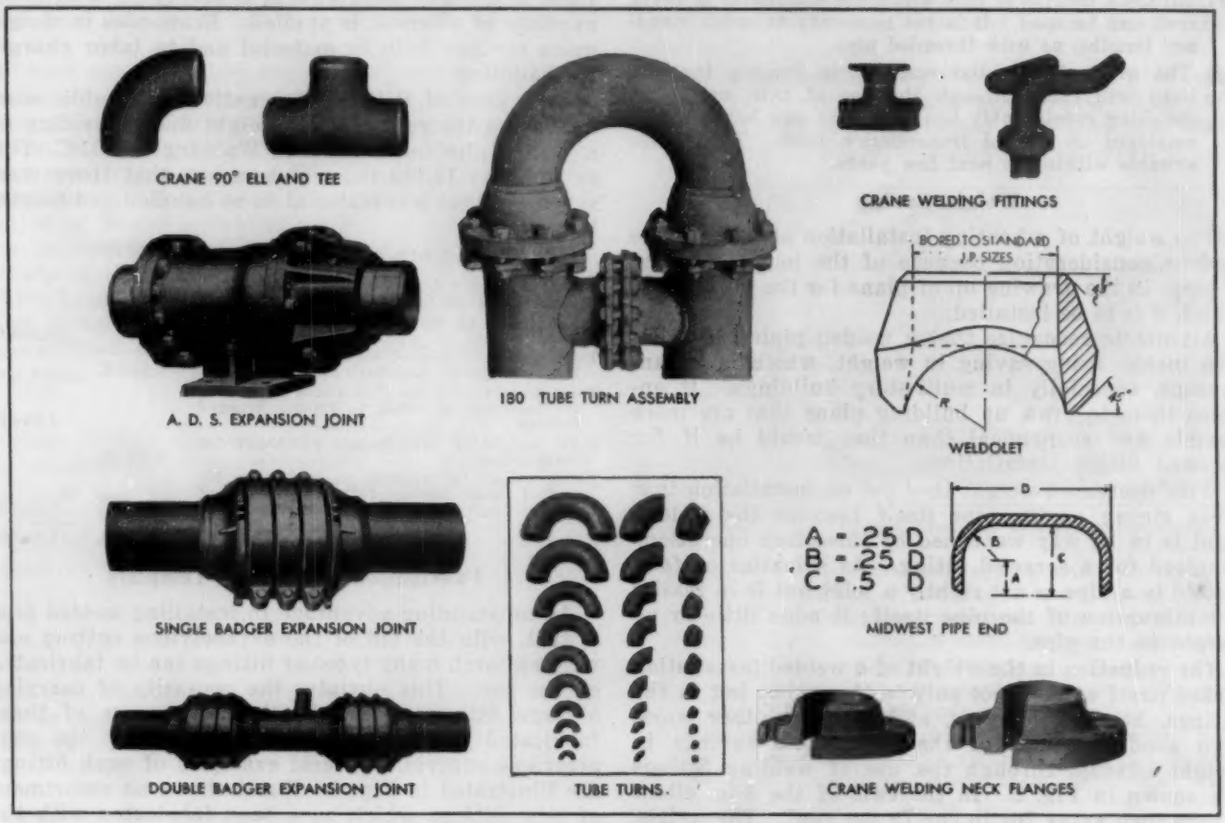



Fig. 6—Commercial Welding Fittings

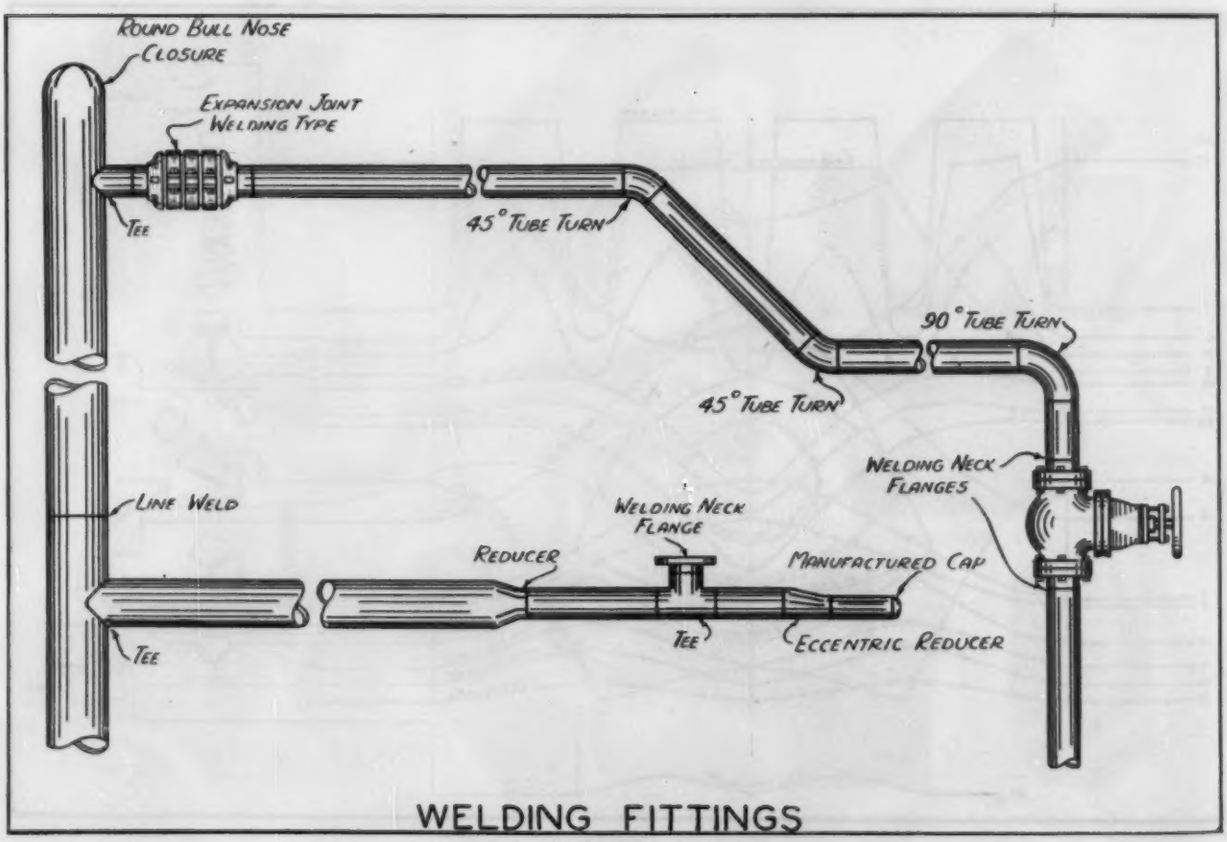



Fig. 7

trated in Fig. 5, the lines of intersection for these fabricated fittings are easily and accurately laid out by the journeyman welder on the job. A compact, durable fitting of the same strength as the pipe itself and weighing much less than a screwed fitting is produced. Large savings are effected in fabricating these fittings, because short ends of pipe that would ordinarily go to the scrap pile are utilized.

### Fabrication of Headers

As the welding of pipe in heating installations has really only come into its own and been accepted as standard practice within the past five years, it may seem strange to some of us in looking back to find that for fifteen years all-welded headers HAVE been accepted as standard practice. At present the old screw fitted header is obsolete.

Until about two years go, all-welded headers were ordinarily fabricated in shops, often at a great distance from the job. This practice resulted in heavy freight bills. Today, since the journeyman has learned pipe welding in a vocational school, these headers are being fabricated on the job with the oxyacetylene cutting and welding torch.

This improved procedure not only effects notable economies but brings back to the journeyman a part of his trade which had been taken away from him because he did not know how to weld. It rightfully belongs to him and should be and is part of his trade.

Every architect and contractor knows from experience that weight handling and maintenance all cost money. A header fabricated with the welding and cutting torch, while primarily BETTER, is also superior from these other standpoints.

### Welding Fittings

One of the recent important developments in the heating industry is that large manufacturers and supply companies, recognizing that welded pipe is quickly superseding the old screw-fitted type, have developed and put on the market a number of welding fittings, such as—tube turns, elbows, tees, reducers, expansion joints, bull nose closures, return bends,

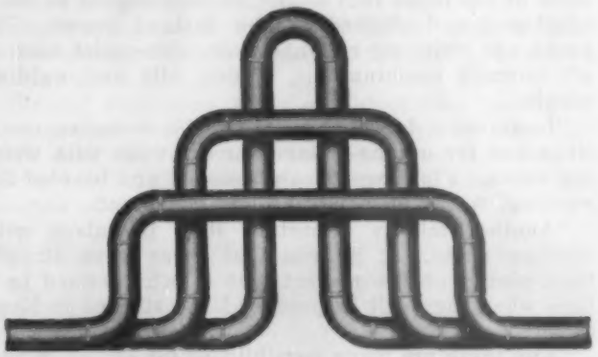
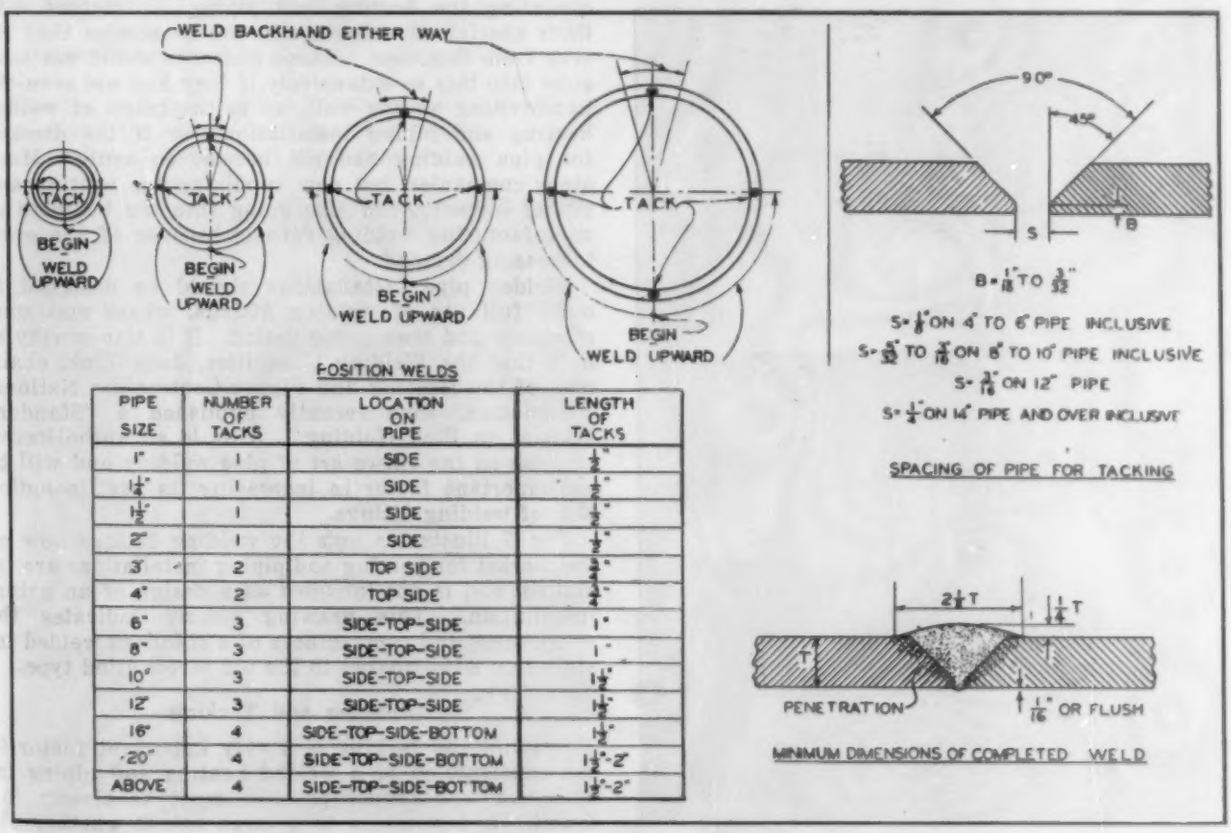


Fig. 9—Welded Expansion Loops

welding neck flanges for valves, etc. A number of these are illustrated in Fig. 6.

In the April 21, 1931, issue of *Power*, page 34, George Edwards, engineer, said the following about welding fittings in the heating and piping industry:

"An old dream of mine is coming true. For years I have been waiting for the time when I could go to a box and pull out a tee, elbow or other fitting, all ready to weld directly into the job.




| PIPE SIZE | NUMBER OF TACKS | LOCATION ON PIPE | LENGTH OF TACKS |
|---|---|---|---|
| 1" | 1 | SIDE | 1/2" |
| 1 1/4" | 1 | SIDE | 1/2" |
| 1 1/2" | 1 | SIDE | 1/2" |
| 2" | 1 | SIDE | 1/2" |
| 3" | 2 | TOP SIDE | 3/4" |
| 4" | 2 | TOP SIDE | 3/4" |
| 6" | 3 | SIDE-TOP-SIDE | 1" |
| 8" | 3 | SIDE-TOP-SIDE | 1" |
| 10" | 3 | SIDE-TOP-SIDE | 1 1/2" |
| 12" | 3 | SIDE-TOP-SIDE | 1 1/2" |
| 16" | 4 | SIDE-TOP-SIDE-BOTTOM | 1 1/2" |
| 20" | 4 | SIDE-TOP-SIDE-BOTTOM | 1 1/2"-2" |
| ABOVE | 4 | SIDE-TOP-SIDE-BOTTOM | 1 1/2"-2" |

Fig. 8—Good Pipe Spacing, Tacking and Welding Practice

"Pipe fittings for welding are on the market, and in this issue you will find an announcement of another line. I haven't yet had a chance to check the range of fittings covered, but tees and ells are a good start.

"Still, I look forward to the day when the power plant Jack Horner can sit in his corner and pull out any desired plum in the shape of a welding fitting.

"Without waiting for catalogs, which will show all the fittings that can be bought now, I can tell you some of the items that sooner or later should be manufactured and stocked as the demand grows. We could use reducing ells and tees, side-outlet tees in all common combinations, 45-deg. ells and welding nipples.

"I can see a lot of applications for reducing couplings and for unions (flanged or screwed) with welding necks. Pipe caps, nicely rounded and beveled for welding, would be handy around the plant.

"Another mighty important item is valves with welding necks. It is true that these have already been placed on the market, but I look forward to a time when they will be produced and stocked in large quantities.

"And there are many possibilities for radically new types of fittings. When enough people want them, they will be made."

It is most convincing that large and old-established manufacturing and heating supply companies such as Crane Company, Midwest Piping & Supply Company, American District Steam Company, E. B. Badger & Sons Company, Tube Turns Company, Walworth Company, and many others now have on the market welding fittings that possess many advantages over the old screwed fitting.

Large sums of money have been spent by these companies in developing welding fittings and in acquainting the heating and piping contractors with their special advantages and the economies that accrue from their use. These concerns would not have gone into this so extensively if they had not seen the handwriting on the wall, as to the trend of welded heating and piping installations, or if the demand for pipe welding had not become so acute. Many other companies, not now supplying the heating and piping industry, are also going into the business of manufacturing welding fittings because of the ever-increasing demand.

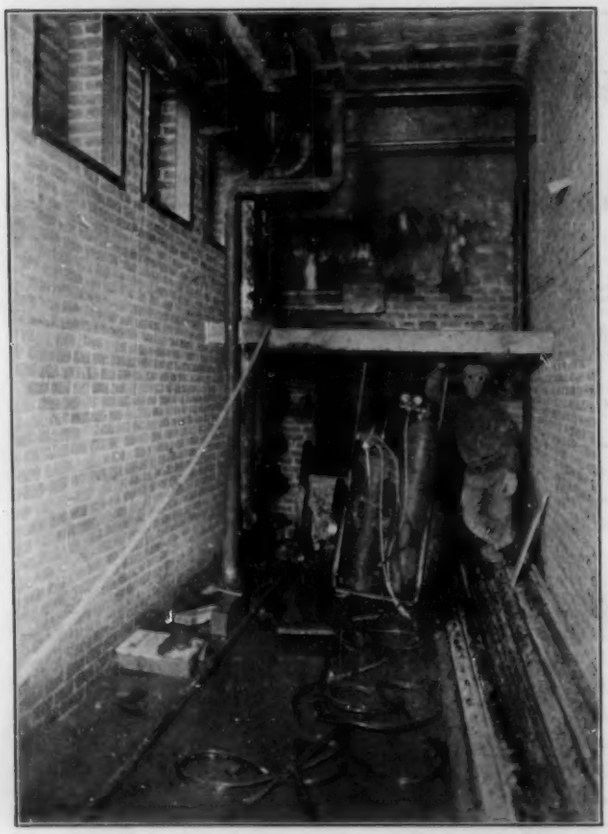


Fig. 10—Main Steam Lines Entering Tunnel

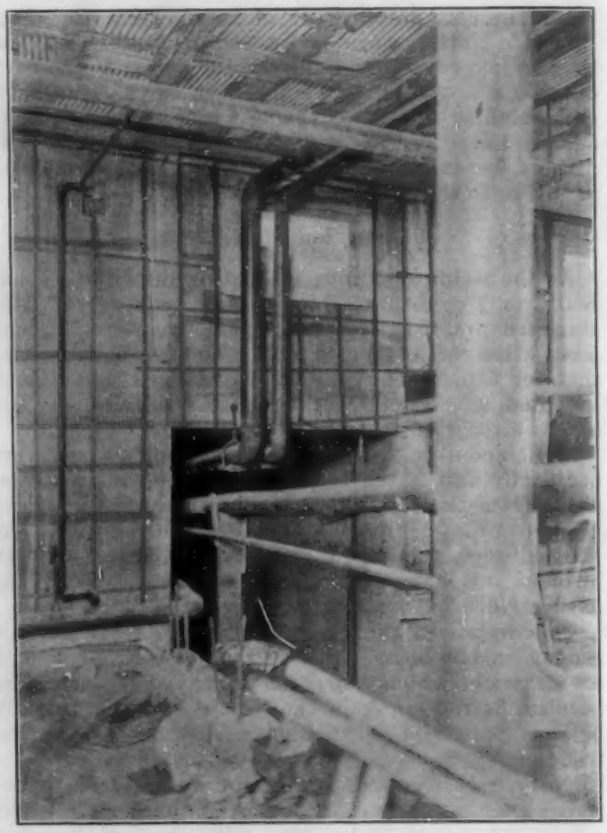


Fig. 11—Welded Piping at Tunnel Exit

Welded pipe installations should be designed to make full use of welding fittings, where maximum efficiency and economy is desied. It is also worthy of note that the Welding Committee, John Zink, chairman of the Heating and Piping Contractors National Association, have recently published a "Standard Manual on Pipe Welding." This is an authoritative treatise on the entire art of pipe welding and will be an important factor in increasing its use, including that of welding fittings.

Fig. 7 illustrates how the welding fittings now on the market for heating and piping installations are installed, and is not intended as a design of an actual installation. This drawing clearly indicates the smoothness and compactness of a standard welded installation as compared to the old screw-fitted type.

### Spacing and Tacking

Spacing and tacking is a very important factor in the construction of a welded heating and piping installation and proper practice must be closely followed. It determines to a large extent whether the pipe weld, when cooled, will be free from locked-up

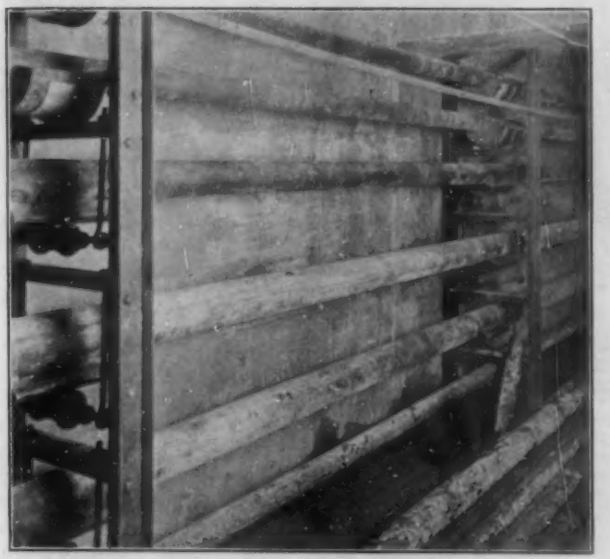


Fig. 12—Arrangement of Welded Piping in Tunnel

stress, which is very desirable, or under tension, which is undesirable.

When the pipe is properly lined up, beveled, spaced and tacked, the pipe edges contract evenly after welding. This keeps the pipe line straight, maintains full strength in the weld and assures uniform expansion and contraction while in operation.

A pipe properly lined up and beveled, but improperly spaced and tacked, has uneven contraction strains which throw the pipe out of line. This prevents penetration, takes more time per weld, is more costly and causes the weld to be under tension. When expansion and contraction occur in service, a failure may result. Such failures are sometimes charged to welding when they should be charged to ignorance or neglect.

Spacing and tacking has received much consideration from the American Gas Association. Fig. 8 shows what is considered good practice.

Fig. 13—Welding Drain Nipple in Steam Line in Tunnel

### Expansion and Contraction

In a welded heating and piping installation, the problems of expansion and contraction are no different than in a fitted installation. No unusual conditions exist, and expansion and contraction are provided for in practically the same way as in a fitted job. The same types of expansion loops and joints are installed, but in a welded installation the contractor has the additional assurance of durability and reduced maintenance costs.

An assortment of expansion joints with welding necks, designed expressly for welded piping, is shown in Fig. 6.

Welded expansion loops are illustrated in Fig. 9. It is evident that a loop of practically any shape desired may be fabricated on the job without delay, using welding fittings (say 1½ radius) and straight lengths of pipe.

Fig. 14—Fabricating an Eccentric Reducer on the Job

Among the advantages of welded expansion loops may be cited:

(a) Uniform mechanical strength. The walls are uniform in thickness. There is no thinning of outside walls or thickening of inside walls and no flattening of cross-section, such as occurs in the manufacture of an expansion loop made from a single piece of pipe.

(b) Full size of pipe throughout loop—less resistance to flow.

(c) Speed, simplicity, economy, flexibility and precision in designing and erecting. Can be made to fit into any available space.

(d) Fabricated on the job. No delays, less expense.

### Adaptability and Portability of Oxyacetylene Apparatus

The oxyacetylene welding and cutting unit on a heating and piping installation offers adaptability and portability far superior to the tools, scaffolding and pipe threading machines incident to the old screwed fitting method, to say nothing of the time lost in preparation, etc., when following routine.

The only tool now necessary is the welding and cutting unit, which can be readily moved from point to point with little or no expense. If desired, the

Fig. 15—Welding a Welding Neck Flange to End of Pipe

journeyman can do his welding on several floors without moving his cylinders, simply by extending the lengths of his hose.

There is no time lost waiting for special fittings because any kind of a fitting that is needed can be fabricated on the job. In addition, welds can be made in a confined space where it would be impossible to install screwed fittings.

### Welded Piping in the Home

A rather general impression in former times was that, in a welded heating installation, it was only economical to weld pipe above 2 in. in diameter and that all pipe below this size should be joined together by the old screw-fitted method. This is a fallacy that has been exploded. There are just as many economies to be had in the welding of the smaller size pipe as there are in the larger size pipe.

The welding of pipe in the heating plants of bungalows and one- and two-family houses is being done at present to a greater extent than is commonly known, and this type of work has proved profitable to the contractor. In welding a small house heating installation, the same standards of beveling, spacing and tacking should be carried out as with pipe of larger sizes.

### An Illustration in Point

At the start of this paper, it was stated that the paramount reason for all-welded heating installations being at present accepted as standard practice is that plumbers and steamfitters now learn how to weld pipe in vocational schools. Probably the best way to demonstrate this is to show illustrations of a large pipe welding installation, which was made possible by this very condition.

This work was done in the new Springfield Hospital, Springfield, Mass., by a contractor of that city, who had previously done little pipe welding and had experienced difficulty in getting steamfitters who knew how to weld pipe.

Our company was called upon for advice regarding this installation and requested to recommend steamfitter welders. The contractors were furnished with four journeymen who had learned pipe welding in a vocational school equipped with a proved pipe welding course, lectures, charts and pipe templets. Work was started without delay.

Fig. 10 shows main steam lines coming down from ceiling and entering into the tunnel. For all bends and changes of direction of pipe in this installation tube turn fittings were used and all welds were made with the oxyacetylene process. Note the portable truck unit which consists of cylinders, regulators, hose, welding torch and cutting attachment.

Fig. 11 illustrates welded piping at tunnel exit. These are high pressure steam lines which supply the nurses' home.

Fig. 12 shows the arrangement of the welded piping in the tunnel. The pipe sizes range from 4 to 8 in. Several of the welds in piping are visible. Note the saddle arrangements at pipe racks and the compactness of the layout. Spacing and tacking of these pipes was carried out in accordance with Fig. 8. As a result, these lines are very straight. The welding of the pipes in this tunnel offered considerable difficulties, but was completed before the date specified.

Fig. 13 shows continuation of welded piping in the tunnel from Fig. 12, at the point where it changes its position from the wall to the ceiling. A journeyman steamfitter welder is shown welding ¾-in. drain nipples into high-pressure mains.

Fig. 14 pictures a 5-in. to 1½-in. eccentric reducer being fabricated by a journeyman steamfitter welder, using the cutting attachment on the welding torch. A 5-in. tube turn has been welded to other end of pipe. The photograph gives an idea of the accuracy with which it is possible to fabricate fittings on the job. This section is to be fitted and welded into pipe line.

Fig. 15 shows a journeyman steamfitter welder welding a welding neck flange to end of pipe, prior to its being set up in line and bolted to valve.

Fig. 16 illustrates two 10-in. all-welded steam headers, which were entirely fabricated by journeymen steamfitter welders on the job with the oxyacetylene cutting and welding process. Standard welding neck flanges were used for headers and pipe lines shown. All bends in pipes were made with tube turns. These headers and piping are located in a space about 12 ft. square. There are 196 welds within this small area.

Fig. 17 is a view of steam lines passing through the

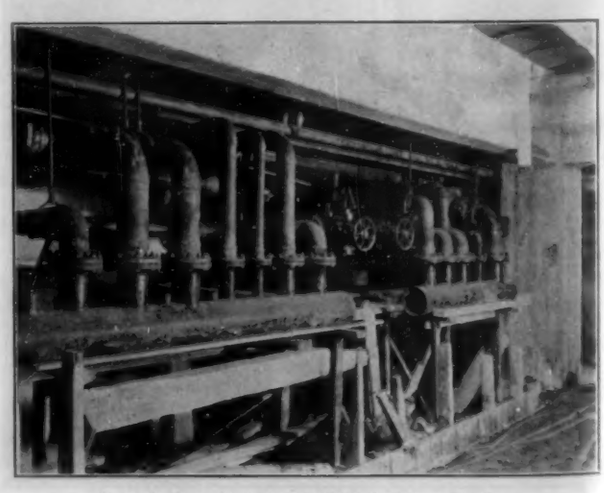


Fig. 16—Two 10-Inch All-Welded Steam Headers

pump room. The size of the larger pipe shown is 5 in.

Fig. 18 illustrates a section of the overhead piping in the building. A 5-in. to 3-in. eccentric reducer is shown, installed in the line.

The entire installation includes nine thousand six hundred (9600) feet of piping, not including the headers, all of which are welded. Pipes used range from 2 in. to 10 in. in size.

### Conclusion

The large supply companies have recognized that, as manufacturers and producers, they assume a responsibility where their products are used. As a result they have accumulated through engineering research, experience and study, a vast amount of special information which is gladly furnished to customers.

They have developed, for vocational schools, valuable educational data and methods of training. For the heating and plumbing industry, they now offer to vocational schools a complete proved copyrighted pipe welding course, lectures, charts and pipe templets. High-grade engineering assistance in teachers' training is also furnished.

With this educational data and engineering assistance, plumbers and steamfitters now learn to weld pipe efficiently and economically under a proved method of group education; a step-by-step training where every man has his own individual welding and cutting unit and each is doing the same thing at the same time, on pipe only.

The old system of teaching adults in trade school classes, whereby each student was working on something different from the other, and learning things that he could not apply to his own trade, is obsolete and is rapidly disappearing. We are more than ever becoming specialists and a good place to start is in the vocational schools.

Fig. 17—Steam Lines in Pump Room

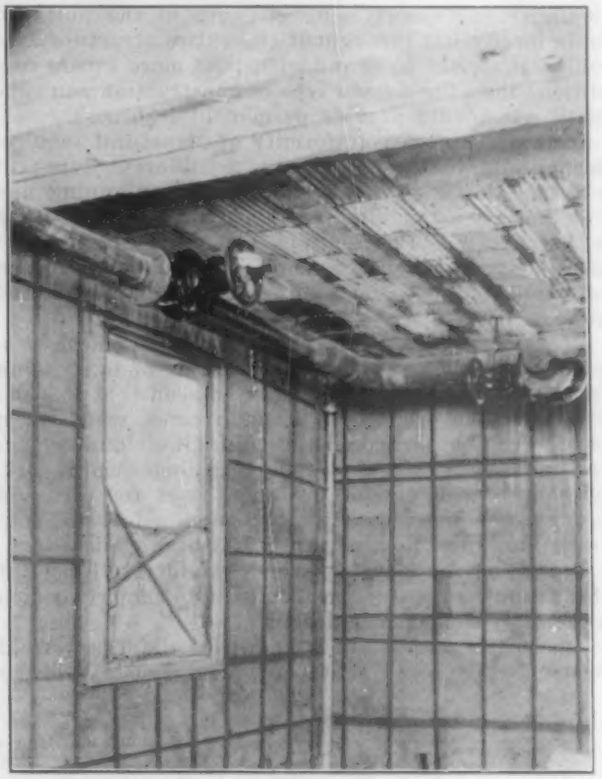


Fig. 18—Overhead Piping in Building

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# The Future of Welded Ship Construction

By J. KJEKSTAD

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by J. Kjekstad, Consulting Welding Engineer, United Dry Docks, Inc., N. Y.

THE problems confronting the builder of welded barges and ships are probably more varied than in the ordinary run of construction jobs. Aside from all the minor details which must be taken care of in all welding work, marine construction requires careful consideration due to the constantly changing, continuous and often excessive stresses which floating crafts are subjected to.

The points to be considered in the building of welded crafts we shall here confine to design and method of construction, which should meet the following requirements:

(a) Maximum structural inherent and permanent efficiency.

(b) Economical in designing, fabricating and erection.

(c) Economical in operation and maintenance.

Under (a) comes brute strength of the hull, not only locally but throughout the entire structure as a unit. It should meet and withstand more severe conditions than the riveted type of construction can cope with. It should provide permanent tightness.

Under (b) comes uniformity of structural requirements and their adaptability to different types of crafts. Uniformity and simplicity in planning and calculating, a minimum of fabricating and a method of erection which not only is economical but makes it possible to arrange the whole construction program on a production basis, eliminating the "hand tailored job" with its many evils.

Under (c) the operating economy is most pronounced in oil tankers, where cleaning of tanks is an important item. It will readily be seen that if a design could be produced, without frames, which form small rectangular panels, needing individual cleaning, and which form gas pockets underneath deck, without brackets, clips or other traps for dirt and hidden breeding places for corrosion, a forward step in the design of floating crafts has been made.

Searching for a system which would fulfill most of these requirements, led my company to adopt two such systems of welded ship design.

One of these systems is known as the Truss Weld System. Fig. No. 1 shows a typical Truss Weld designed tank barge, (A) being a plan view, (B) a longitudinal and (C) a transverse cross-section.

The internal structure, although being a single, self-supporting unit, is split up into a comparatively large number of cells, formed by longitudinal, transverse and vertical truss members, connected by welding at their intersections. To change the shape of an individual cell it becomes necessary to change the shape of the adjoining cells, which, in turn, have other adjoining cells, finally taking in the entire number of cell units. An idea of the strength of this internal construction may be formed by noting Fig. 2, representing a load test on a single cell, which was tested to destruction. The load applied in a diagonal direction, on the circular plates, reached 10 tons before any, deflection took place, after which the cell members, 3-in. x 3-in. x ¼-in. angles, gradually deflected under continued loading until fractures in the members occurred but without showing any fractures in the welding. In a 116-ft. x 36-ft. x 10-ft. barge there are approximately 2000 such cells, and it would therefore require approximately 20,000 tons applied diagonally to distort the hull. This type of internal construction eliminates the ordinary transverse and longitudinal framing. The load, if on deck, is carried directly through the vertical columns down to its foundation, in this case, the water under the bottom.

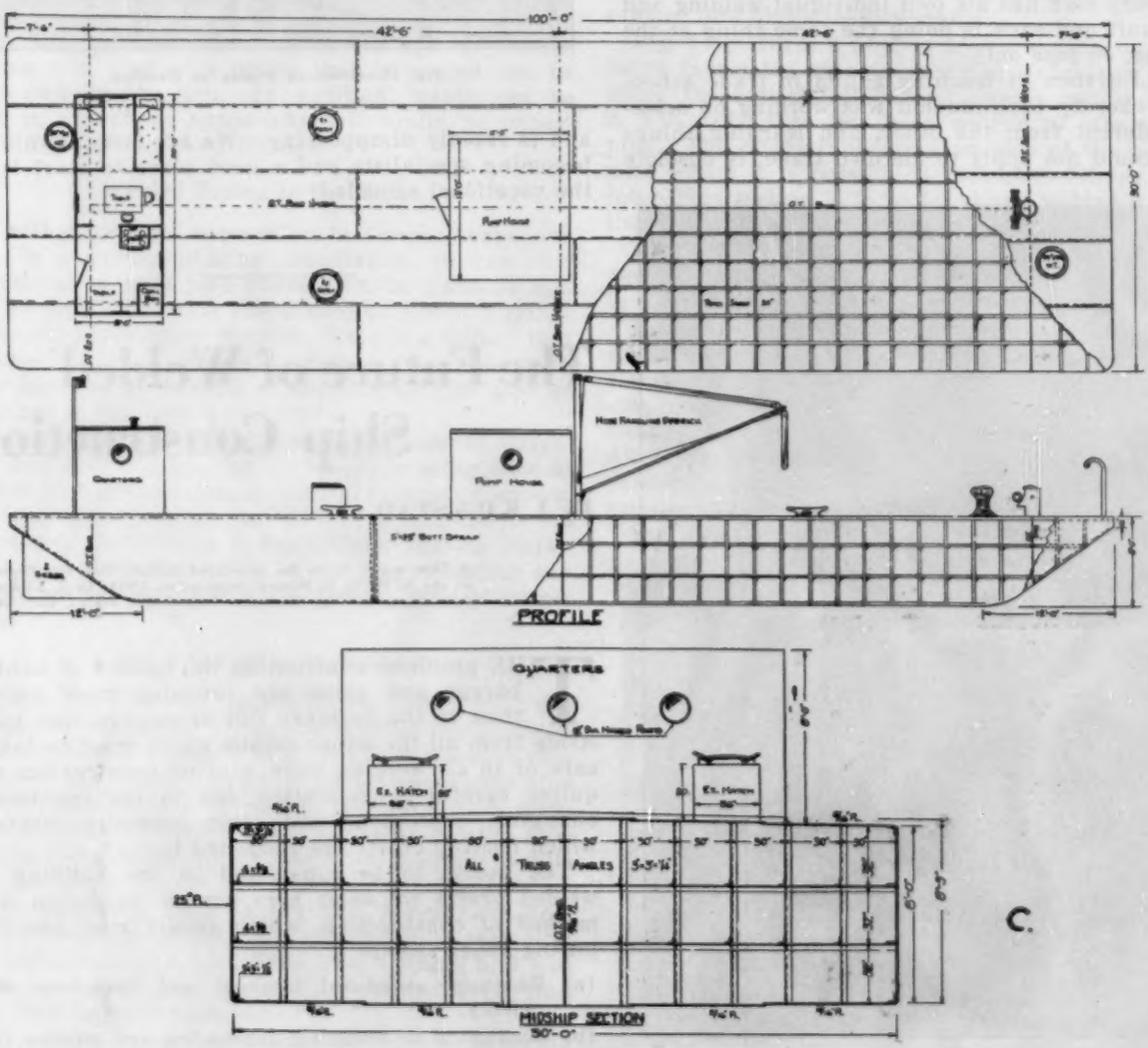


Fig. 1—150,000 Gal. Tank Barge

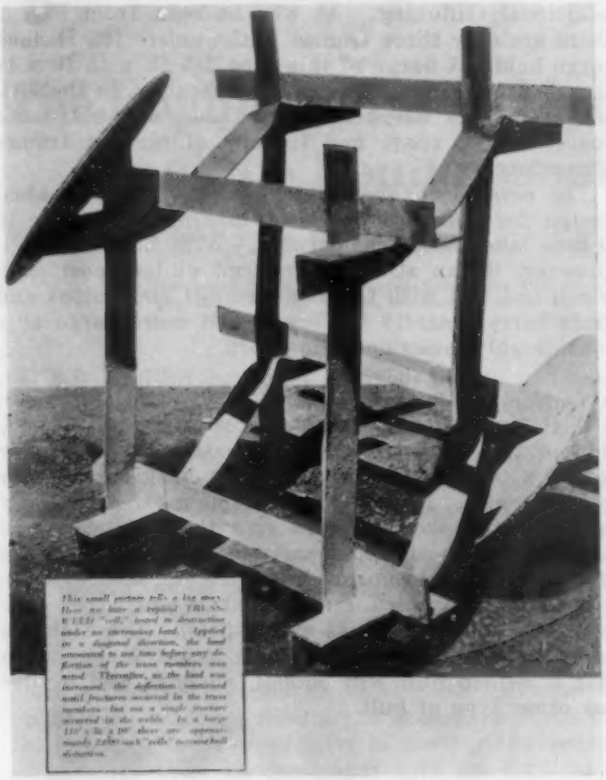

Fig. 2

For liquid cargoes conditions are similar, only with lesser stresses. This type meets all requirements under paragraph (A), as structural efficiency is tremendously increased in this system notwithstanding a considerable reduction in the weight compared to other methods of ship construction.

As to the requirements under paragraph (C). It will be seen at a glance that the uniform structure calls for a minimum of designing and calculating. As to fabricating and erection. This consists of laying bottom plates upon which the trusses, all built in a jig, are erected and tackwelded to the bottom. The bulkheads, side and deck plating, are thereupon erected against, around and on top of the truss unit, which is absolutely rigid in itself, and it then remains to complete the welding of seams, truss angle members to shell plating and welding the trusses at their intersections. All plate seams being lapped and welded continuously on both sides of lap insures a joint efficiency with full plate strength. The overlapped type of seams also eliminates locked in stresses, which are unavoidable in all types of butt joints, and which is the main cause of the few failures in welding. The lapped joint further eliminates any shearing to size of plates as the ordinary mill tolerance is close enough. In corner seams, with corner reinforcing angle, seam is welded inside along both toes of angle and outside where plate edges form an open 90 deg. joint in way of angle heel. Where butt seams in side plating occur, these are either lap welded or, where a flush outside plate surface is wanted, the seam is backed up with a butt strap on inside. Cavities and dirt traps are eliminated.

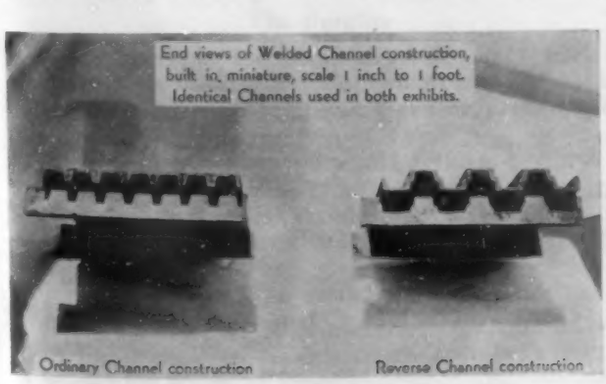
End views of Welded Channel construction, built in miniature, scale 1 inch to 1 foot. Identical Channels used in both exhibits.
Ordinary Channel construction
Reverse Channel construction

Fig. 3

Among the various types of crafts built on this principle, there are self-propelled and tow oil tankers, deck barges, derrick barges, pile drivers, conversions of coal or grain barges into oil barges up to 5000 tons capacity.

Of all these crafts, some of which have been operating for years, not a single instance of failure necessitating repairs has occurred. Inspection of welds inside and outside has disclosed no greater deterioration than the plating itself. When one considers that these crafts have been subjected to normal and abnormal abuse such as groundings, collisions, fire, overloading, operation as in one case, for four years without drydocking, and painting, it is felt that a rightful claim can be made for the superiority of the welded hull over the riveted.

### Reverse Channel System

The other system of shipbuilding adopted by the United Dry Docks is the so-called "Reverse Channel System." This system was developed to overcome the shortcomings of the truss-weld system for certain types of crafts, primarily the type which carries dry

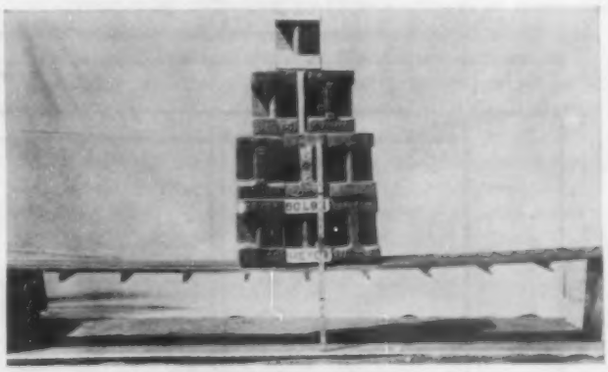

Fig. 4—Reverse Channel Under Heavy Load

cargo in the hold, for which purpose the truss weld type of craft is unsuitable. An attempt was also made to develop a system which would overcome certain difficulties in the design of long, shallow crafts, or, in other words, concentrate the maximum percentage of weight into effective longitudinal strength. This, we believe, has been accomplished in the reverse channel sysetem, where the proportion of weights between shell plating and internal construction is approximately six to one, or better, with a moment of inertia far in excess of any other type of construction, having the same hull weight. From Fig. 3, showing a section of channels placed with the webs in the same plane, and a section showing the reversed channel system, it is obvious, without calculation, that the reverse channel section is the stronger, but difficult to realize that the section modulus of the reversed chan-

nel section is approximately six times greater than that of the other. Fig. 4 shows the reverse channel section with a very large load. The tremendous increase in strength of the reversed section, however, is relatively unimportant considering many other advantages obtained in this design. The flanges of the channels overlap each other to form a lap welded seam. This seam is located in the neutral axis of the section, and, therefore, subjected to minimum stresses. The lap weld eliminates warping and locked-in stresses, frequently the cause of failure in butt welded sections. A feature in this design, which, in some cases, may be invaluable, is the tendency of the section to stretch out transversely in the manner of an accordion rather than fracture, as in the case of plate or other types of flat surface construction, if a dangerous grounding or collision occurred. Objections may be raised to this type of construction, as in any other type of construction, but they are few and insignificant, and can be eliminated entirely. The points in favor of this type of construction for certain purposes, are apparent, however, and is best illustrated by referring to Fig. 5, showing a typical coal barge. This type of open barge has been almost entirely built of wood as the structural requirements have made the price of steel construction prohibitive. This type, however, produces a shell plating which is stiff enough in itself to require very little additional stiffening. As will be seen from Fig. 5, there are only three frames in the entire 100 ft. long cargo hold. A barge of this type 235 ft. x 45 ft. x 11 ft. was recently built and put in operation on the Mississippi. This barge required transverse bulkheads spaced 24 ft. apart and thereby eliminated frames altogether.

The reverse channel system is, moreover, an ideal design for automatic welding, making it possible to reduce labor cost considerably. With hand welding, however, it can still be produced at less cost than wood, and will with the same overall dimensions and draft carry from 15 to 20 per cent more cargo at a considerably lower operating cost.

### Future Advances

With the ever increasing interest, use and recognition of the many advantages possible to obtain by welding, there will unquestionably be a demand for welded crafts. Progress in this line must necessarily be slow, and should be, to give the producers and consumers both an opportunity to observe the results of the test, never improved upon as yet, that of time. With all the welded crafts, makes and types now operating under all sorts of conditions, there should be ample material upon which to base the conclusion that a welded hull will outsell, outwork and outlive any other type of hull.

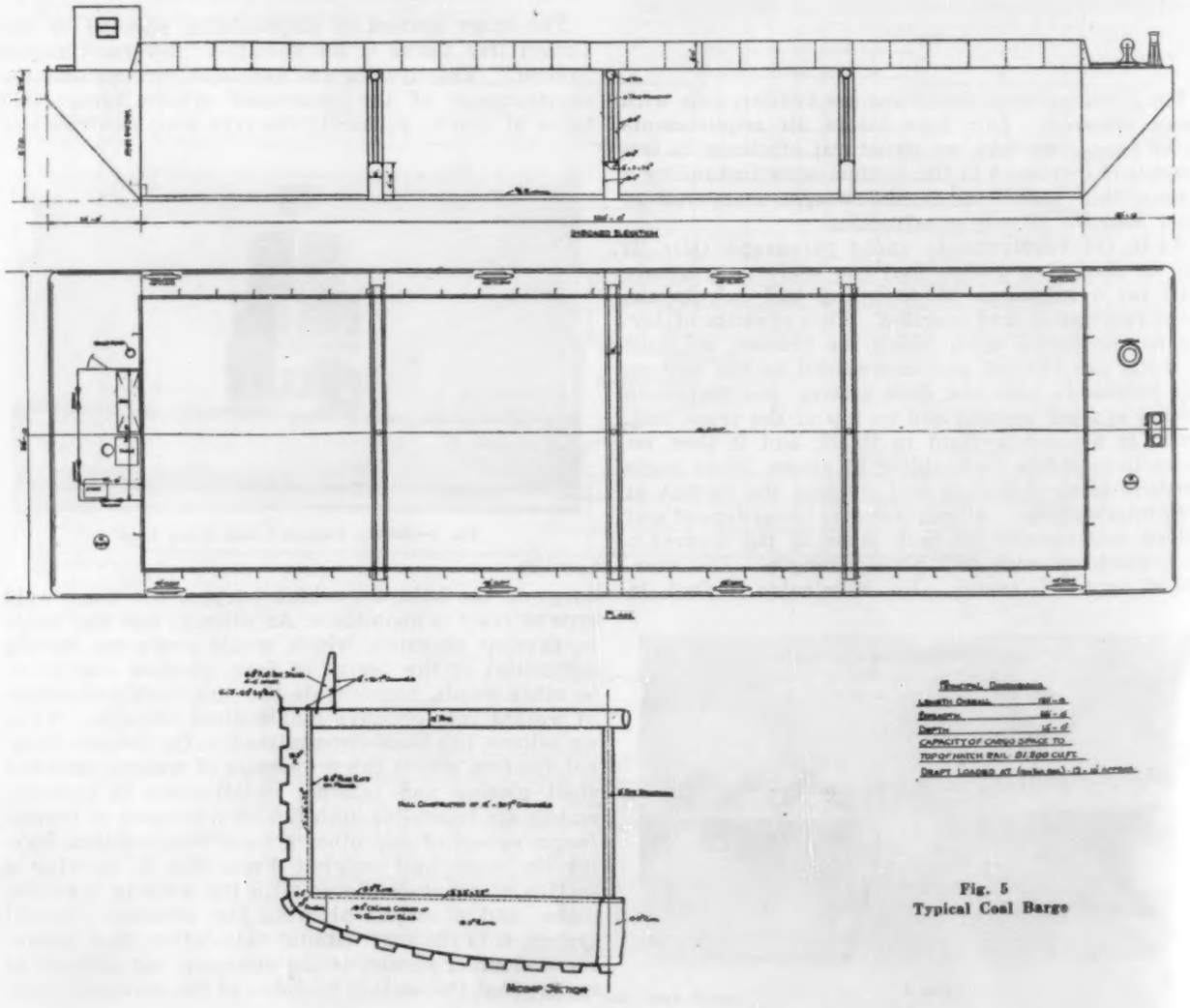

Fig. 5
Typical Coal Barge

# The Engineer, the Welder and the Foundryman

*By* P. J. HORGAN

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by P. J. Horgan, of the General Electric Company, Lynn Works.

PROGRESS has been defined as an increasing control of our environment which in turn includes all the circumstances external and internal that influence the realization of our desires.

The multiplying inventions of the present era are but the new tools with which man is continually freeing himself from the drudgeries of the past and harnessing the powers of nature to provide those creature and mental comforts which form the basis of the home and sustain the family life as the keystone of civilization.

A survey of industry in 1931 indicates that Welding plays an important role as an efficient and economic method of obtaining results. It is essential then that the Engineer to be progressive in meeting the demands of Industry must be conversant with the facilities at hand in order to strike the proper balance of when to use the new tool, Welding, as an alternative for the forging, pressing or casting.

Engineers take pardonable pride in the scientific achievements of the past and approach the future with a feeling of optimism in their ability to solve new problems as they arise.

Today, however, we must acknowledge the ascendency of the Accountant whose job is to keep management posted on the costs of running Industry to insure a reasonable profit.

The previous decade has been a sellers' market in which the Engineer has had full freedom to realize the fruits of his imagination and the demands for his creations have been sufficient to warrant only the successful functioning of the new methods and processes.

The next decade will probably be a buyers' market in which the Engineer must also study the frame of mind as well as size of purse of the prospective purchaser. He must recognize that practically every manufactured commodity can be obtained from one of several concerns whose reputation for reliability insures quality and delivery of the goods on promised time.

## The Forging

The forging is the ideal structure since work is performed upon the material while hot and forced either by a series of hammer blows or pressure into the desired shape.

The pressing is virtually a cold forging.

Either of these processes involves considerable manual labor or high initial expense dies with proportional upkeep upon which cost data has been available for some time.

## The Foundry

The Foundry has been necessary for centuries to meet the demand for shapes which were both impractical and too costly to forge.

It may be interesting to digress to point out that in the decade of 1880-1890 the Foundry was the forerunner of our present mass production system since during that period, noting the repetitive nature of the work done by moulders in making stove parts, they followed the work of Colt in manufacturing firearms on a quantity, low labor cost interchangeable part basis and substituted machine moulding for the previous arduous hand labor.

To present the case of the Foundry briefly and within the scope of this paper we must recognize the mental status of Foundry executives. It was not so long ago that the first contact the Foundryman had with his order for castings was the presence of the patterns and core-boxes at the Foundry door. His training had been to find ways and means to produce castings from patterns as they appeared, for he assumed that the Engineer and patternmaker were conversant with what was wanted. His skill, brains and experience were to be used to get results only and changes in design to facilitate moulding or to reduce hazards, naturally couldn't come from a group who confined their activities toward managing their own particular end of the business.

The outstanding reaction of Welding as a benefactor to the Foundry is the fact that the Engineer in designing an alternative for the casting has indicated to the Foundryman the fundamentals required and has thereby helped him to analyze his Foundry problems and given him the courage to point out to the Engineer design changes which not only materially affect the quality of the casting but also reduce moulding and coremaking costs.

Such a process of reasoning is mutually educational to the Foundryman and Engineer.

The designer of today, then, in order to reason logically whether he is to cast or to weld, must be conversant with the material and labor costs of both methods.

To make a casting we first must have a pattern. Patterns may be simple templates, sweeps, strikes, etc., requiring skilled moulding knowledge and labor. And then they may be block patterns mounted or unmounted on boards or metal vibrator or match plates to suit the modern machines for jolting, squeezing, pattern drawing, etc. The amount of money put into a pattern is directly proportional to the expected production and quality of casting desired.

The former practice of a moulder spending five minutes drawing a pattern and then using up an hour in patching his mould is rapidly being replaced by up to date pattern making with the parting line built into the pattern itself to take full advantage of the machine equipment at hand reducing labor costs to a minimum. The substitution of cores for draw-backs and sundry tell-tales are but simple examples of the progress of the cooperative efforts of the patternmaker and Foundrymen.

To make a mould we must ram, jolt, squeeze or sling sand into the flask around the pattern, patch, butt-off or reinforce the mould where necessary, set cores, close the mould, cut gates, pouring basin, etc., all of which represents moulding labor. To this of course we must add labor of sundry adjacent operations such as making cores, cleaning, snagging, etc. The amount of foundry labor in each case depends upon the complexity of the pattern and core boxes and the facilities for handling the flask, the sand and withdrawing the pattern.

Gray Iron in the molten state ready to pour into a mould costs on an average one and one-quarter cents per pound

To arrive at the cost of a casting then, we should know the weight of the iron, multiplying it by the cost per pound at the spout, add thereto the individual labor prices for the foundry operations and then the necessary indirect expenses commonly called overhead. The author wishes to stress this last item since he has seen incorrect fabricating savings in the journals of the Welding trade where overheads on welding were omitted on the basis that castings were material only whereas castings do involve the three items of material, labor and overhead.

Molten steel at the openhearth spout is of the order of one and one-half cents per pound. Labor in the Steel Foundry is comparable with iron practice except that allowances must be made for the added precautions for handling hotter metal, more headers to feed the casting and more work actually performed in cutting risers, cleaning, snagging, etc. Extra expense also reflects in the overhead incident to a larger amount of dry sand moulding, etc.

Cost of non-ferrous castings in bronze or brass depends upon the amount of copper, zinc, lead, tin, etc., used.

### Welding

The use of steel plates and structural shapes has been greatly enhanced by the rapid improvements in our facilities for welding, a greater respect by designing engineers for the welding art in general and a desire to take full advantage of any ways and means to reduce costs.

Boiler Plate or steel shapes cost about two and one-half cents per pound.

In cutting plate with oxygen and acetylene, hydrogen or city gas we not only have the factor of 25 per cent to 40 per cent scrap because of the relation of the various contours to the rectangle of the plate itself but also the cost of the gases which are practically 100 per cent of the direct labor in doing the cutting.

The direct labor prices involved in getting shapes ready for welding using the conventional rolling, bending and flanging machinery are well understood.

Precise data on the cost of the welding operation itself while fairly well established in individual factories is still in a state of flux. The percentage of time permitted for watching the arc varies from 40 per cent to 80 per cent. Allowances for fatigue depend upon local conditions.

The amount of heat which can be applied depends upon the nature of the structure to keep distortion at a minimum. One pound per k.w hour of energy seems to be recognized as the correct basis of calculation for metal deposited by the electric process.

To determine the cost of a fabricated structure then, we must start with the cost of the plate, add percentage for scrap, then direct labor costs of forming, gas cutting and welding plus indirect expense.

### The Engineer

Neither castings nor fabrications can be classed into the antiquated pooled groupings to meet the demands of the modern Engineer for precise cost comparison data. Each method must be studied on its individual merits if cost is the final arbiter. If the Engineer has only one set of facilities at his disposal, i.e., either Foundry or Weldery, then that is another story. Fortunate indeed is the Engineer who can turn to either, for competition does work wonders.

Enthusiasts for welding have freely predicted the early disappearance of castings from the marts of trade. This will not come to pass. It seems much fairer to predict that shapes will always be in demand where the making of a mould into which is poured one continuous mass of molten metal will be the preferred form at lower cost.

While weight is a factor in many designs to absorb vibration, it is not in itself the determining factor of cost. Cases are known where the original weight was doubled and because of increased wall thickness, core shifts, etc., were permissible to the extent that patterns were mounted on moulding machines with reduction in moulding labor sufficient to make the revised cost less than the original.

On the other hand Engineers need no longer feel reluctant towards the welded form. Thousands of tests on welds prove their reliability. Improvements in welding facilities are being made yearly and personnel trained for workmanship, supervision and inspection is a guarantee of results.

There are innumerable cases where wall sections in the past have been determined by Foundry practice and the Engineer has been handicapped to obtain full advantage of his material.

With steel equal to cast iron in compression, twice as strong in tension and two and one-half times as stiff, and reliable data at hand on the strength of various types of welded joints, the Engineer is now in a better position to dispose his material along the lines of true engineering logic.

In many cases the welded structure is superior to any other method and the designs are more flexible, being independent of existing patterns and dies.

Shorter and surer deliveries are possible since we are dealing with steel plates and shapes of known characteristics.

Fabrication can be carried on under the same roof as the machine shop and responsibility for results can be well defined, since, with steel and facilities for forming and welding at hand, the Engineer is merely required to put his drawing in the shop and say, "this is what is wanted," specifying the date when.

The large Electrical concerns are not advocating the use of welding merely to promote the sales of the welding apparatus which they make. They are using welding in the right place because it is the right way to get results They have their own Foundries, Forge and Press shops. Motor and Generator frames, switchgear and transformer tanks are, in the main, simple cylindrical shapes easily rolled to the right diameter with welded seams to complete the work. They have much in common with the tank and pipe maker.

The welding trade journals are replete with examples of fabrications which clearly indicate the resourcefulness of designers.

If only a single machine frame or a jig or a fixture is wanted, generally speaking, fabrication is quicker and cheaper.

Experimental machines with fabricated frames, because of opportunity to gas-cut openings or weld new bosses, brackets or projections, should be a solace to the designer who wants to change here and there to improve results. Single purpose machines lend themselves to the welded form for the same reason.

The correct final costs, however, of apparatus to be sold to the public can only be determined by Engineering analysis based upon material, labor and overhead expenses.

# Maximum Stress: Its Influence on Cost and Service Life of a Structure

*By* EVERETT CHAPMAN

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by Everett Chapman, Director of Engineering & Research, Lukenweld, Inc.

THERE are "sore spots" in every structure which constitute the main burden of every engineer's responsibility. It is within these minute localized areas of importance that we may look for the reasons behind our so-called factors of safety, unit cost and that insidious bit of mechanism known as fatigue failure: insidious because it may terminate the useful life of the machine in one year, three years, or fifteen years. Best engineering practice fully recognizes the point of maximum stress within any given structure as essentially fixing the life of the machine.

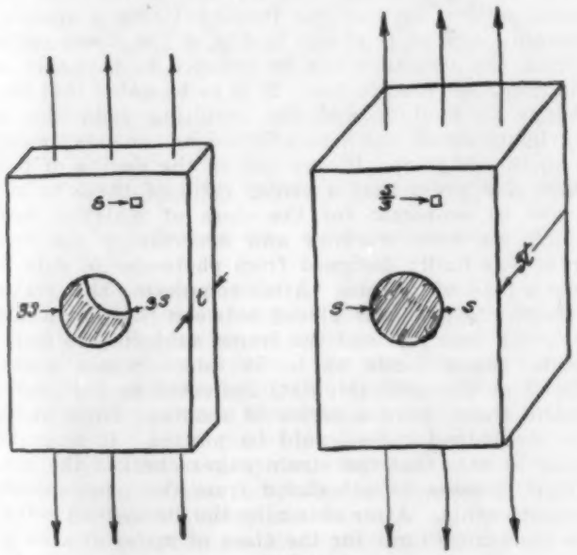


Fig. 1

In determining the physical distribution of a given amount of metal which subsequently has to perform a certain function, the ideal structure is attained when each cubic inch of material is working at exactly the same unit stress as any other cubic inch of material. Deviations from this unattainable ideal always result in a structure which is heavier than the one which might have been used. Service loads can very rarely be placed with their line of action exactly coincident with the central axis of a cross section. Pure tension is rare. To illustrate: a C-frame punch press designed to a permissible deflection at a 25-ton load requires around 2500 lb. of steel properly placed. If the nature of the problem were such that pure tension could be produced in supporting this load, a mere 30 lb. of steel would suffice. We thus arrive at

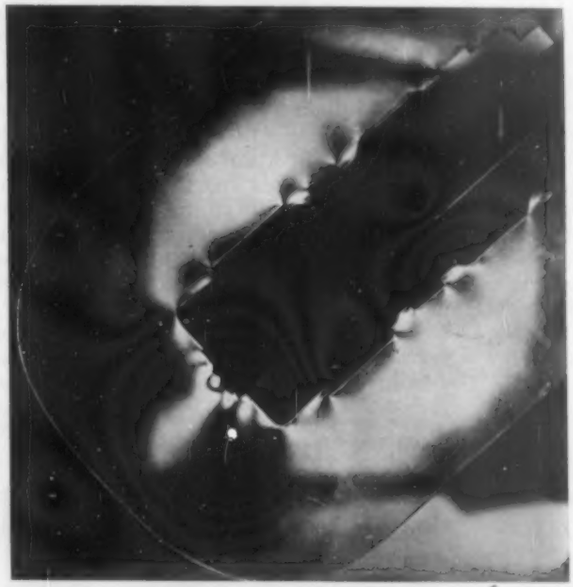

Fig. 2—Photoelastic Picture of Model of Sheet Mill Housing, Showing Regions of Maximum Stress Induced by Chuck Mountings

the general thought that perhaps the most significant thing governing the size of a structure is the introduction of bending moments or, in more general terms, eccentric loads.

While these eccentric loads produce, grossly, the usual combinations of tension and compression with which every engineer is familiar, most distressing phenomena occur when these moments are focussed at some sort of a change in contour, either gradual or abrupt. It is at these changes of contour that the most damaging increases in stress occur. Stress concentrations of as high as ten times the average stress may be recorded at some minute point where the metal is in no position to go to work.

Let us examine an elementary case which will in a rough manner illustrate the effect of this increase in stress upon the cost and service life of a structure. Suppose we take the classical case of a rectangular plate having tension forces acting at right angles to two parallel edges and having a hole drilled in the center. Let us suppose that the tensile forces are of a recurrent nature, subjecting the plate to a reversal of stress. Theory indicates that at the edge of the hole a stress exists whose magnitude is three times the stress values throughout the remainder of the plate. The immediate exigency that rears its head is that if the average stress was just under the endurance limit of the plate material there is a point in the structure where the stress is considerably over the endurance limit, and we may eventually expect a fatigue failure at this point. A crack will start at the point of maximum stress and this crack will propagate itself through the remainder of the material at a rate dependent upon the frequency of stress reversal. Let us now correct this structure so that the service life will be lengthened to an economic value. In order to bring the stress at this one small point down to a value which is the same as that in the plate before the hole was drilled, it will be necessary to increase the thickness of this plate three times. This results, of course, in an extreme waste of material in those regions where the stress had already been low enough. The material cost of this structure has been tripled.

Let us examine a few more practical cases. The steel industry uses what is known as a jump mill for the rolling of thin sheets. With the top roll riding on the bottom roll, the construction is such that terrific impact loads are placed upon the screw and housing every time a sheet passes through the rolls. Each chuck brass is mounted in a dovetail, and several of these dovetails are machined on the inside of the frame. A photo-elastic examination of a model of a stressed housing shows that there are twenty-four possible places for a fatigue crack to start. These housings are worth some two thousand dollars a piece and report has it that 600 of them are broken every year: the break occurring at "any" place along the side with a marked preference shown for the lower corners. The failure shows clean metal and this results in a general conclusion that the structure was too weak in the first place. It is, therefore, heavied up considerably at an appreciable increase in cost. These sharp notchlike indentations in the side of the frame coupled with the severe impact loading of this structure result in an economic waste of a high order. Hatchways cut in the top deck of a ship introduce just such concentrations. What might be the ultimate cost of an unsuspected condition of this nature?

Fig. 3—Conventional Press Frame Contour Showing Two Severe Concentrations

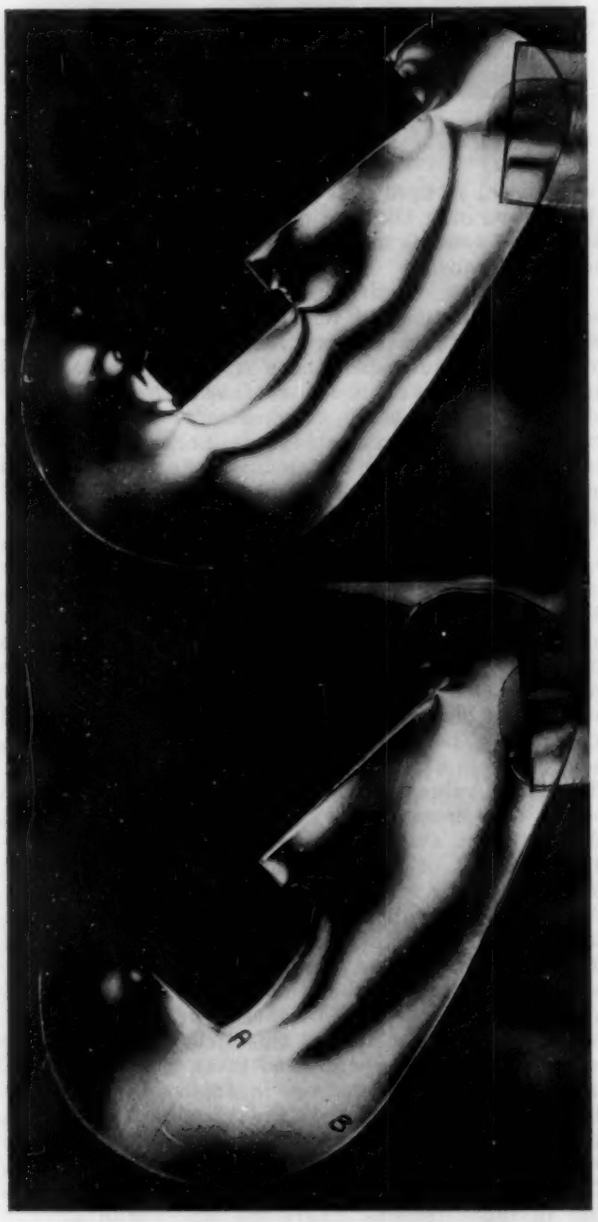


Fig. 4—Modified Contour of Press Frame Showing Relief of the Highly Stressed Areas of Fig. 3

Photo-elastic examination lends itself very readily to the determination of the location and magnitudes of these sore spots, while its greatest value lies in checking the remedy.

Another apt illustration of the differences that may be effected in a structure by slight changes in contour is afforded in Figs. 3 and 4. The conventional type of C-frame punch press is shown in Fig. 3. It is to be noted in this photo-elastic picture that there are two very serious stress concentrations in this structure as it has always been designed. The small reentrancy at the back of the platen is due to the age old requirement that planing tools must run off into thin air. The reason for the reentrancy at the top of the guides has never come to the writer's attention, and yet the contour is common to several well known frames. Rough measurements of stress at these changes of contour give stress ratios of 12 to 1 and 8 to 1, respectively. Experience will recount many failures at these points. The remedy for this structural discrepancy is decidedly not to increase the metal section back of the throat. Using a modified contour, such as is shown in Fig. 4, the stress ratios within the structure can be reduced to a spread of the order of three to one. It is to be noted that this change in contour and the resulting reduction in maximum stress has been effected by removing metal from the original. It was felt in the design of this particular press that a stress ratio of three to one would be economic for the class of material with which we were working and accordingly the first press was built: designed from photo-elastic data to take a load of 25 tons. After completing this frame a hydraulic jack was placed between the platen and the main bearings and the frame subjected to incremental static loads up to 50 tons. Strain gages, placed at the critical points indicated in the photo-elastic study, gave a series of readings from which the stress-load curve could be plotted. It is gratifying to note that the strain gages checked the predicted stresses as calculated from the photo-elastic measurements. After obtaining the stress-load curve, the endurance limit for the class of material used in the construction of this frame was spotted on the curve and the corresponding safeload noted, which happened to be 40 tons. We can thus safely say that this press, if never loaded to exceed 40 tons, should have an indefinite life.

Fig. 5 gives this stress-load curve for the locations mentioned. The point of maximum stress is comfortably relieving itself with an attendant exhibition of a very desirable property: ductility. It will be noted that the curve showing the behavior of this point departs from a straight line at a load of 50 tons while the stress in the rest of the frame is as low as 6000 lb. per square inch. The extreme importance of ductile materials at a point such as this cannot be overemphasized. It is just the difference between scratching a piece of glass, thereby effecting a clean and easy break, and attempting the same thing with a piece of lead. It is a heaven sent quality of the

materials that engineers are blessed with that they will stretch before breaking; and the particularly fortunate part of the whole matter is that they stretch at just the spot that needs to be stretched. It is nearly divine. Any structure is a better structure for having been relieved at its critical points, and the structure, if overloaded before being put into service, will automatically do this. There is a great deal of good elementary structural philosophy to be had through meditation upon the shape that a structure would like to take. The closer a given design approximates this "comfortable" shape, the closer that design will be to a theoretically perfect thing. To the writer's mind one of the perfect engineering conceptions is the modern suspension bridge. Every engineer has a warm sympathy for the structure as an entity. All is quite right.

Machine structures fabricated by welding are very likely, due to the inherent geometric abruptness of the process, to include many of these areas of high stress concentration. Weld fillets themselves are necessarily more abrupt than any corresponding change in contour ever achieved in a casting. Illustrations are included here to show the type of stress concentration that occurs around several types of fillets. A particularly bad case is illustrated in Fig. 6, where a typical case of undercutting due to improper welding technique has been observed. Ductile metal in a weld fillet is basically important. The modern welding processes will deposit a metal having a high degree of ductility, but even that is not enough. The parent metal alongside the weld is generally overheated and in cases where the carbon content is too high it will show a sorbitic structure that is more brittle than the annealed parent metal. It is therefore necessary, in dynamically loaded structures, to thoroughly an-

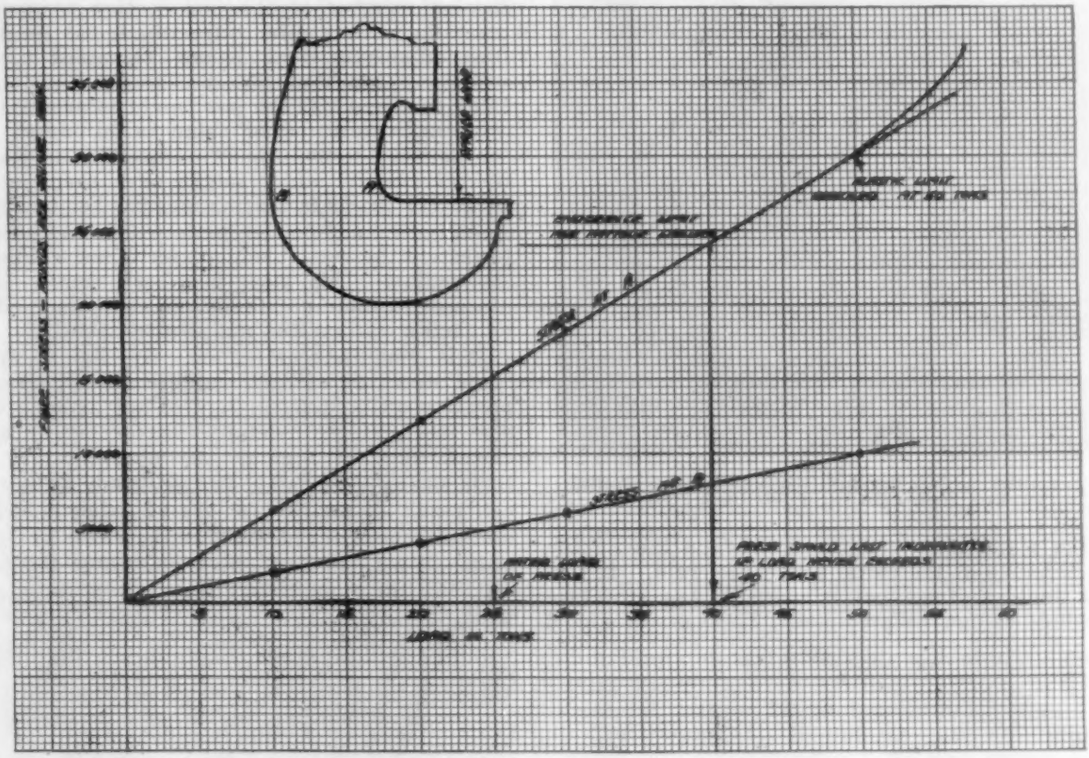

Fig. 5—Load Stress Curve Giving Results of Strain Gage Measurements Over Critical Regions of Completed Press

Fig. 6A — Point A Marks Stress Concentration in Undercut Fillet Weld Subjected to Couple

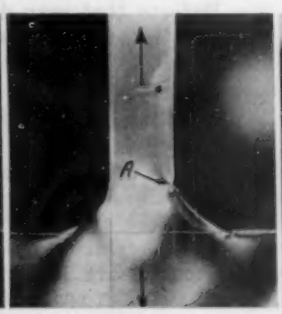


Fig. 6B — Point A Marks Stress Concentration in Undercut Fillet Weld Subjected to Tension

Fig. 6C — Point A Marks Stress Concentration in Undercut Butt weld Subjected to Tension

Fig. 6D—Showing Extremely Complicated Stress Distribution in Unscarfed Double Fillet Weld Subjected to Tension. B Marks Two Regions of High Stress

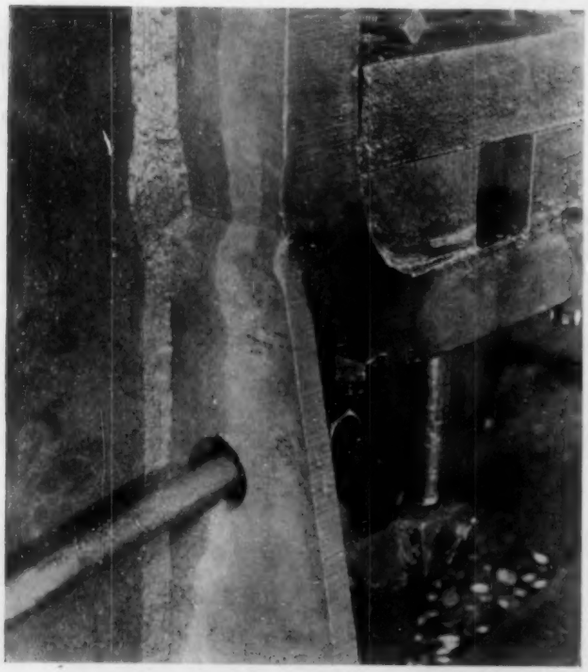

Fig. 7—Showing the Easy Change in Contour Afforded by Bending the Main Tension Member of This Large Press

neal the piece after welding to restore the ductile characteristics of the metal round the weld. If this is not done, uniform performance of the structure as a whole cannot be predicted. The case in Fig. 6 showing the undercutting as a phenomena which will raise the stress becomes an even worse condition when one realizes that unannealed material around the zone of high stress will not be of a ductile nature.

A certain amount of ingenuity must be exercised at the point of major stress in a large structure. Fig. 7 shows the construction at the critical point of a large press capable of exerting a 525-ton blow. The tension member of the box section comprising the main frame is a 4-in. plate which has been bent to form an easy gradual change of contour at the point where we can look for exceedingly high concentrations of stress. If the equipment is available this is an economically proper thing to do, simply because the bending costs little in comparison to the cost of the weld metal which might have been put at this point had the main tension member been made in two pieces. The sub-bolster plate which has been placed to restore the available die space is not welded around the radius. This plate has been merely locked in place at suitable points around its outside edge. The notched condition has not been restored.

It is somewhat of an anomaly that to produce a large structure of a proper gross design and incorporating an economical service life at an economical cost the engineer must go microscopically exploring certain small regions whose importance far exceeds their size. Properly considered, study at these points can result in smaller factors of safety which immediately reflect themselves in the initial cost of the unit. It will, in particular, guarantee the long service life upon which all reputations for good work must be founded.

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# Factors Affecting the Weldability of Steel

*By* WILMER E. STINE

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by Wilmer E. Stine, Research Engineer, The Lincoln Electric Company.

MOST welding engineers have at some time or other had welds made that were not all that could be desired. The technique, etc., had seemed perfect, proper currents, etc., had been used and yet porosity had resulted.

It was in an endeavor to eliminate this that a study of the relations of the chemical constituents of steel was started by our research department.

Electric arc welding will be considered herein as that method of fusion welding in which the seam to be welded is filled with molten metal melted by the heat of an electric arc and allowed to solidify, thus forming the weld.

Electric arc welding may be divided into three classes as follows:

a. Metallic arc welding with bare or washed electrode.
b. Metallic arc welding with shielded arc electrodes (electrodes with a heavy coating to protect the arc from the oxygen and nitrogen of the atmosphere).
c. Carbon arc welding with a shielded arc.

In the first two methods the weld is composed of metal from two sources, viz., metal from the electrode and metal from the plates or material being welded. Consequently the resulting weld is affected by the parent plate, the electrode material and its coating.

In the third method, the welds can be satisfactorily made without the addition of filler material and the weld metal composed of metal from only one source, viz., the plates being welded. Therefore, carbon arc welding with a shielded arc seems to offer the best method of welding for a study of the factors that effect the welding characteristics of steel.

Defects that may develop because of certain characteristics of the steel forming the weld are as follows:

a. Cracks.
b. Slag holes.
c. Gas holes.

Causes of the first class of defect seem to be fairly well understood. This investigation is largely confined to the causes of the latter two classes of defects.

Gas holes are not formed to any appreciable extent where the arc is in an oxidizing atmosphere. The weld metal in such cases is overoxidized and has very little ductility and will not be a high quality weld. High quality arc welds can only be made with a shielded arc. Gas holes become an important factor in such welds.

Fig. 1 shows the type of welding equipment used in this investigation. Fig. 2 shows two plates butted together for welding. Fig. 3 shows the type of weld made. A part of each weld was broken open for examination.

The arc was shielded from the oxygen of the atmosphere by the burning of an impregnated fibrous autogenizer fed through the arc at a constant rate.

Standard samples of porous welds were chosen for comparison. These samples were numbered from 0 to 5. Zero being free from any porosity visible to the naked eye. Number 5 was a very porous weld. These standard samples are shown in Fig. 4.

The cooperation of several steel manufacturers was obtained in furnishing different series of samples for welding tests.[1]

The first series of samples was made by taking very low carbon, low manganese steel and melting it in an

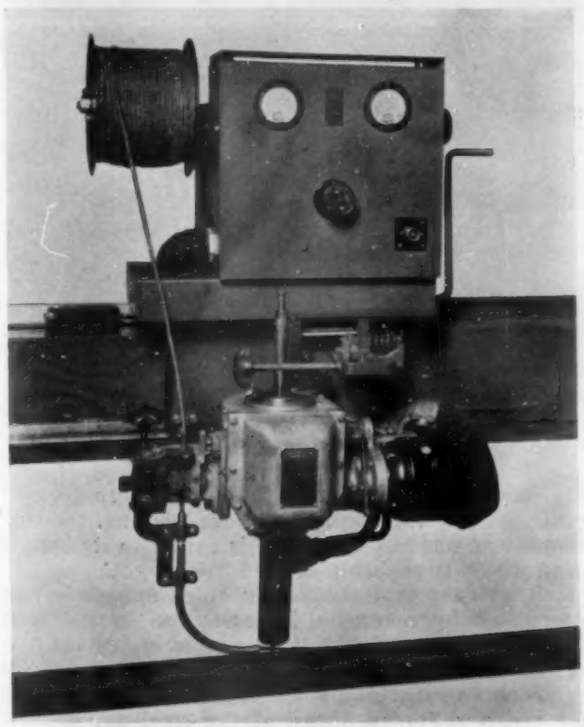


**Fig. 1**
Automatic shielded carbon arc welding equipment used for making welds to determine factors that affect the weldability of steel

electric furnace, adding various desired amounts of carbon and manganese. This steel was then rolled into plates and welded.

All samples in this group proved to be poor welding quality. Subsequent tests and analysis indicated that the steel used as a basis for this series of samples had been deoxidized with an excess amount of aluminum and that the aluminum was the principal controlling factor.

The determination of small quantities of aluminum in steel is very difficult and the accuracy very problematical and is therefore not considered reliable.

Analysis of the basic steel in the above series showed 0.018 per cent aluminum.

[1] Acknowledgment is made of the cooperation and assistance of the following steel companies in providing samples for the investigation: Republic Steel Corp.; Carnegie Steel Co.; Corrigan-McKinney Steel Co.; Bethlehem Steel Co.; Illinois Steel Co.; Sharon Steel Hoop Co.; Alan Wood Steel Co.; Youngstown Sheet & Tube Co.; American Sheet & Tin Plate Co.; Jones and Laughlin Steel Corp.

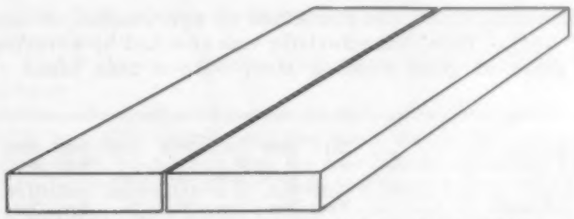


**Fig. 2—Two Plates Prepared and Butted Together for Welding**

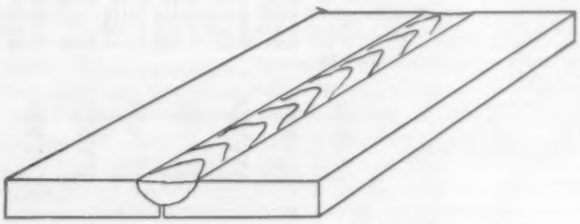


**Fig. 3—Type of Weld Made for Tests to Determine Porosity, etc.**

A second series of samples was obtained from various steel mills, and consisted of fire box, flange and tank steel having a carbon range of from 0.12 per cent to 0.20 per cent. Each steel maker was asked to furnish information as to kind of furnace used, whether the steel was recarbonized, how it was deoxidized, and whether it was killed or rimmed.

A third series of samples of various carbon content was obtained from one steel maker and consisted of steel varying in specifications from SAE 1010 to SAE 1050 inclusive.

A fourth group of samples was obtained from two steel makers and consisted of samples from several heats of representative commercial grades of steel.

The results of a few of the tests are tabulated in Table No. 1. While the results of only 7 tests are tabulated several hundred such tests were made.

It was found that steel which formed slag holes in the weld, as shown in Fig. 5, invariably had been

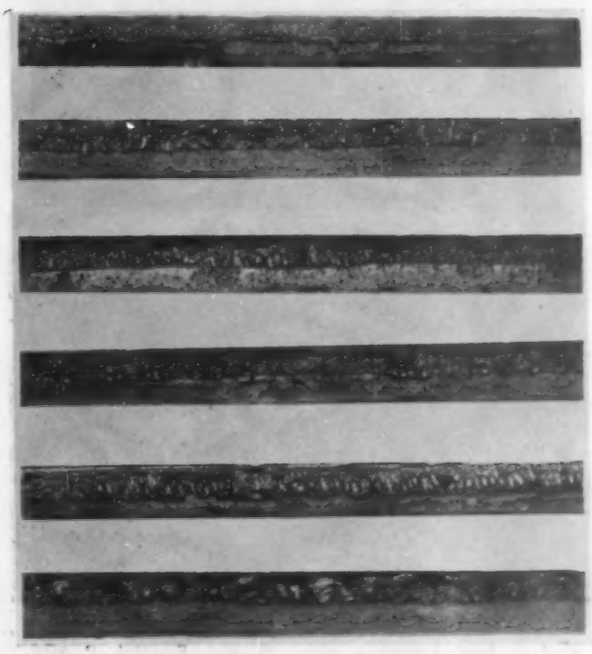


**Fig. 4—Standards of Porosity for Comparison**

aluminum killed and contained an appreciable amount of $Al_2O_3$. This characteristic was checked by covering a piece of good welding steel with a thin layer of

| Sample No. | 101 | 1020 | 1021 | 1015 | 1016 | 1045 | 1050 |
|---|---|---|---|---|---|---|---|
| Steel Maker | A | B | B | C | C | B | B |
| Heat No. | ... | 43581 | 32507 | 7331 | 7331 | ... | ... |
| Furnace | O.H. | O.H. | O.H. | O.H. | O.H. | O.H. | O.H. |
| Recarbonized | Yes | Yes | Yes | No | No | Yes | Yes |
| Deoxidiser Furnace | ... | ... | ... | Spg. | Spg. | ... | ... |
| Deoxidiser Ladle | Mn | Mn | Mn,Si | Mn | Mn | Mn | Mn,Si |
| Deoxidiser Mould | No | No | Al | Al | No | ... | No |
| Aluminum oz./ton | 0 | 0 | 1.5 | ... | 0 | ... | 0 |
| Analysis C | 0.20 | 0.19 | 0.21 | 0.14 | 0.14 | 0.48 | 0.51 |
| Analysis Mn | 0.44 | 0.60 | 0.52 | 0.75 | 0.75 | 0.74 | 0.59 |
| Analysis S | 0.029 | 0.027 | 0.034 | 0.111 | 0.111 | ... | 0.035 |
| Analysis P | 0.016 | 0.018 | 0.020 | 0.016 | 0.016 | ... | 0.025 |
| Analysis Si | 0.02 | 0.02 | 0.07 | 0.012 | 0.012 | 0.20 | 0.08 |
| Analysis Cu | 0.03 | ... | ... | ... | ... | ... | ... |
| Analysis Al | ... | ... | 0.005 | 0.116 | 0.014 | ... | ... |
| Analysis Ni | 0.02 | ... | ... | ... | ... | ... | ... |
| Size–Thickness | 3/8 | 3/8 | 1/2 | 3/8 | 3/8 | 3/8 | 3/8 |
| Welding Amps. | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| Welding Volts | 38 | 38 | 38 | 38 | 38 | 38 | 38 |
| Welding speed in./min. | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| Porosity | 0 | 1–2 | 3 | 4–5 | 1–2 | 5 | 1 |
| Appearance | Good | Good | Good | Poor | Good | Poor | Good |

$Al_2O_3$ before welding it. The result was very similar to that shown in Fig. 5. In order to determine whether this characteristic is a matter of melting temperature of the inclusions, a similar test was made with chromite, which has about the same melting temperature (2050 deg. C.) as $Al_2O_3$. The result was almost identical.

It is somewhat apparent that the behavior of the metal when being melted under the electric arc during the arc welding process is different than when it is melted in the furnace preparatory to being made into castings. It is believed that this difference is because of the higher temperature and relatively greater area exposed during arc welding.

Fig. 5
Weld in Steel—Analysis C .118%, Si .024%, Mn .47%, $Al_2O_3$ .03%. Slag holes are due to high aluminum oxide content

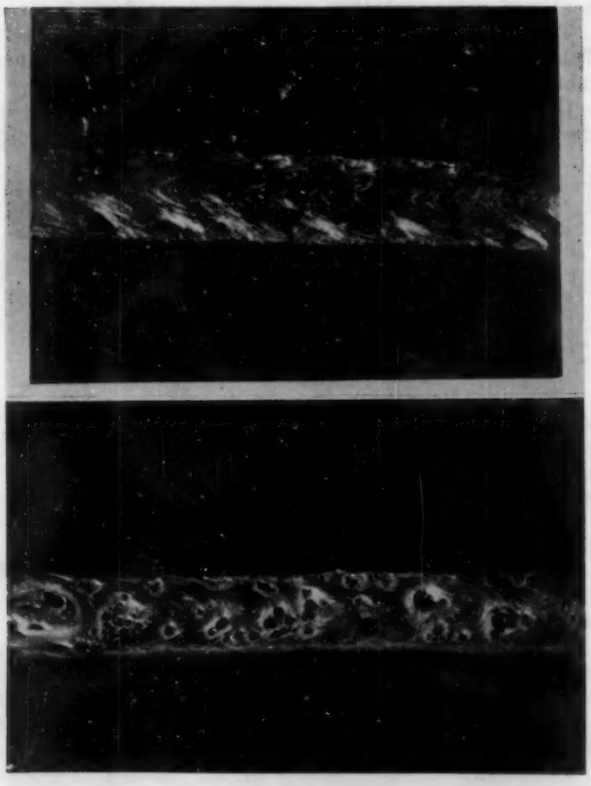


Fig. 6
Weld in Steel—Analysis C .118%, Si .02%, S .112%, P .01%, Mn .68%, Al .116%. Poor welding quality due to high aluminum content

Fig. 7
Weld in Steel—Analysis C .32%, Si .31%, S .026%, P .021%, Mn .73%. Poor welding quality because of high silicon content

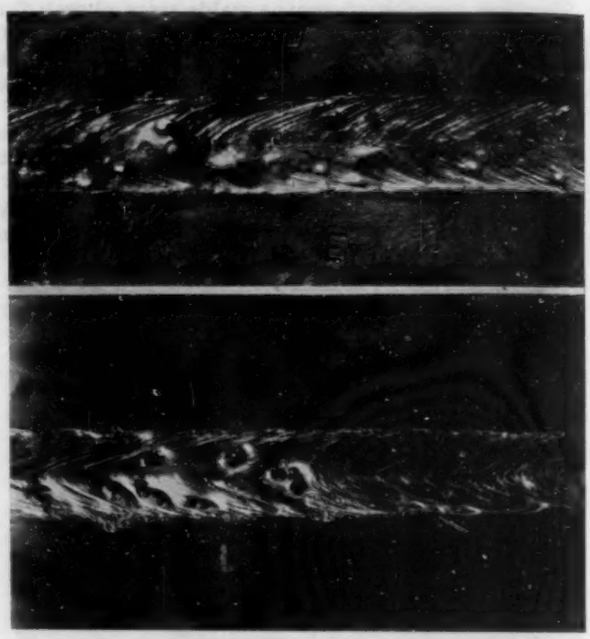


Fig. 8
Weld in Steel—Analysis C .09%, P .016%, S .03%, Mn .41%. Slag forming flux was used on one half of plate. Other half of plate shows gas holes produced by gases absorbed during welding

In steel making or casting the temperature does not greatly exceed 1600 deg. C. In arc welding, the temperature of some of the metal is raised to its boiling point, which is probably around 2500 deg. C.

It is evident that these slag holes or depressions are caused by non-metallic inclusions in the steel which remained as finely divided solid inclusions during the steel making process, but during the arc welding process melted and coalesced to form large globules which solidified ahead of the steel and formed holes or pits in the weld metal. These holes can be eliminated by using a slag forming flux of low melting temperature which will combine with slag of the steel forming a new slag having its melting temperature below that of the steel.

Before analyzing the results of the test as to gas holes we will consider the probable sources of gases which form the holes.

Steel may hold certain gases, such as hydrogen and nitrogen in solution at room temperature.[2]

Carbon monoxide and carbon dioxide may be produced in steel at elevated temperatures as a result of chemical reaction between the carbon of the steel and oxygen in the form of oxides contained in the steel.

Gases may be absorbed from the surrounding atmosphere by the molten metal while it is being welded.

It is a well-established fact that the capacity of liquid steel for holding gases in solution is much greater than that of solid steel.[2] The gases held in solution by the solid steel will not cause the formation of gas holes when being welded, if we could pre-

[2] Prof. A. Sieverts, Z Metallkund, February, 1929, 21, 37.

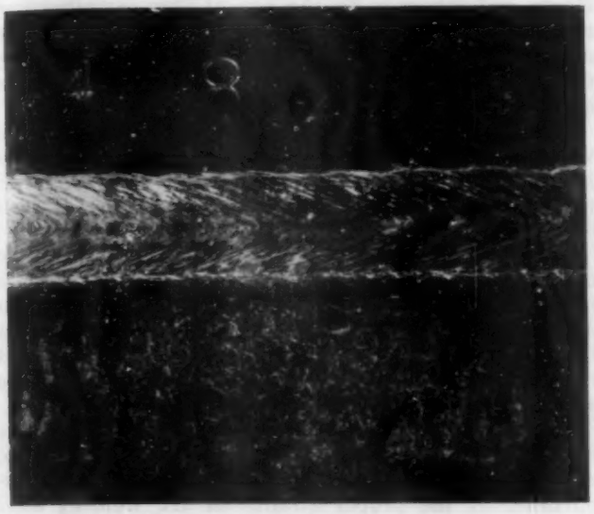


Fig. 9
Weld in Steel—Analysis C .20%, Si .021%, S .029%, P .016%, Mn .44%. Good welding quality

vent the further absorbtion of gases by the liquid steel and the formation of gases by chemical reaction, without decreasing the capacity of the steel to hold gases in solution.

It has been fairly well established that the capacity of steel for holding gases in solution varies directly with temperature and the content of aluminum,[4] silicon and manganese[5] and inversely with the carbon content.[3]

If the capacity of the steel for holding gases in solution is to be maintained at a value equal to what it was in the ingot molds, the aluminum, silicon or manganese must not be oxidized out during welding to any appreciable extent.

In order to prevent the rapid absorption of gases at the high welding temperatures the content of aluminum, silicon and manganese should be as low as practicable.

The oxidation of carbon during welding is permissible, but this reaction should cease before solidification of the weld metal begins.

In other words, chemical equilibrium should be reached between the carbon and the oxygen in the steel at a temperature slightly above the temperature of solidification, and at least one deoxidizing element (aluminum, silicon or manganese) should be present in an amount which will also be in approximate chemical equilibrium with the oxygen present in the steel at a temperature slightly above the temperature of solidification.

Under this ideal condition a steel of given carbon content will have a minimum capacity for absorbing gases at the high welding temperature. Its capacity will increase as the carbon is oxidized out. The formation of carbon monoxide will cease before the metal solidifies and there will be a minimum change in the amount of gas solvent elements such as manganese, silicon or aluminum. Such a steel should, therefore, have the best arc welding characteristics.

The results of the tests seem to verify the theory set forth above. An excess of aluminum, silicon or manganese is capable of causing gas holes in the weld metal.

[3] Smithells "Impurities In Metals," page 106, John Wiley and Sons, New York.

[4] Henry D. Hibbard, Blast Furnace & Steel Plant, January, 1921, 51.

Fig. 6 shows a porous weld caused by an excess of aluminum.

Fig. 7 shows a porous weld caused by an excess of silicon.

The effect of manganese is not so pronounced.

It was also found that the weld metal in dead soft steel may be porous due to gas holes, unless a slag forming flux is used to cover the weld metal while it is molten.

Fig. 8 shows such a weld, one-half of which was made without the use of a slag forming flux. As previously pointed out a very low carbon steel has a high capacity for gases at high temperature, and since there is no appreciable carbon in the steel to be oxidized, the capacity of the steel to hold gases in solution does not increase during welding and consequently the steel absorbs gases in excess of the saturation of the solid steel and some gases are given off during solidification forming gas holes. The formation of these holes can be prevented by the use of the proper fluxing material.

Fig. 9 shows a weld in steel of good welding quality.

In order to determine what manganese, silicon and aluminum content in steel imparted to the steel the best welding characteristics, the analysis of the steels that produced welds practically free from porosity were plotted against the carbon content, as shown in Fig. 10.

The curve for aluminum is not plotted from actual analytical data taken during these tests. Analyses for aluminum were made on several samples used in these tests in accordance with the Bureau of Standards method[8]. This method is admittedly not accurate

[8] Bureau of Standards—"Determination of Small Amounts of Aluminum in Iron and Steel."

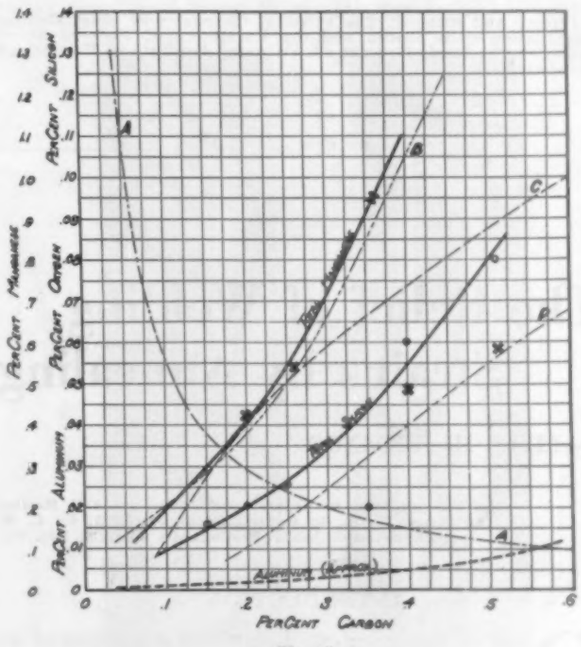



Fig. 10
Curves indicating aluminum, silicon and manganese content of steel of optimum arc welding characteristics as determined by welding tests

Curve A—Carbon-oxygen equilibrium curve at 1595° C. from Herty and others [6]

Curve B—Manganese-oxygen equilibrium curve from Oberhoffer and Schenk [6]

Curve C—Total silicon-oxygen equilibrium curve from data by Herty and Fitterer [7]

Curve D—Free silicon-oxygen equilibrium curve from Herty and Fitterer [7]

to more than plus or minus 0.01 per cent. No satisfactory welds were obtained on any aluminum killed steel which showed by analysis more than 0.018 per cent total aluminum.

It was found by Mr. Brinell that an addition of a given amount of aluminum to steel was as effective in preventing the formation of gas holes in steel castings as about ten times that amount of silicon.

In view of the above and the difficulty of an accurate determination of aluminum in steel, the curve for aluminum was drawn in as 10 per cent of the values of silicon, shown in Fig. 10.

It is evident that the proper control of aluminum in steel plates, sheets, filler rods, or electrodes for welding should be left to the steel maker. The inaccuracy of an analytical determination of aluminum makes it impractical to include limits for aluminum in steel specifications. However, the deleterious effect of a slight excess of aluminum is so great that it must be carefully controlled in the manufacture of steel for electric arc welding.

The values indicated in Fig. 10 for manganese, silicon, are considered to be ideal values. Permissible tolerances have not been accurately determined. The data would seem to indicate that the following tolerances could be permissible.

| | |
|---|---|
| Manganese, plus or minus..... | .10% |
| Silicon, plus or minus ..... | .015% |
| Aluminum, plus or minus ..... | .01% |

The oxygen curve in Fig. 10 is taken from the carbon-oxygen equilibrium curve at 1595 deg. C. by Herty and others.[5] By the use of this oxygen curve the curves for silicon and manganese were checked against the manganese-oxygen equilibrium curve by Oberhoffer and Schenk[6] and the silicon-oxygen equilibrium curve by Herty and Fitterer.[7]

The close conformity of these curves with the individual equilibrium curves established by the various investigators indicate that the equilibrium theory furnishes a correct basis for the manufacturers of steel of good electric arc welding quality.

It has been determined during this investigation that in most cases satisfactory welds can be obtained in welding steel plates which were not in themselves of good welding quality steel by the use of the proper fluxing material, filling or electrode material. Best results can only be obtained when the steel to be welded is of good electric arc welding quality.

Other things being equal, the tendency for gas holes to form increases with the speed of welding. As arc welding speeds are being stepped up the importance of the proper quality of arc welding steel for plates, filler rods and electrode material becomes increasingly important.

### Conclusion

1. Aluminum oxides or any other non-metallic inclusion in steel which has its melting points between the melting point and boiling point of steel will cause slag holes, or pits, in the weld metal of electric arc welded steel unless it is fluxed with some other material which lowers their freezing point below that of the steel.

2. Aluminum, silicon, manganese, or any other deoxidizers having gas solvent properties which are present in excess of the quantity necessary for chemical equilibrium with the oxygen present in the steel at a temperature slightly above the temperature of solidification may cause the formation of gas holes in the weld metal of electric arc welded steel.

[5] Herty and others, Physical Chemistry of Steel Making: The Solubility of Iron Oxide in Iron, Bulletin 34, Carnegie Institute of Technology, Pittsburgh, Pa.

[6] Oberhoffer and Schenk, Theoretische und experimentelle Untersuchungen uber die Desoxydation des Eisens mit Mangan. Stahl und Eisen, Vol. 47 (1927), pages 1526 to 1536.

[7] Herty and Fitterer, The Physical Chemistry of Steel Making: Deoxidation with Silicon and the Formation of Ferrous Silicon Inclusions in Steel, Bulletin 36, Carnegie Institute of Technology, Pittsburgh, Pa.

# The Relief of Welding Strains by Annealing

*By* CHAS. H. JENNINGS

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by C. H. Jennings, Research Labs., Westinghouse Elec. & Mfg. Co.

## INTRODUCTION

ONE of the greatest difficulties encountered in the fabrication of welded machines and structures is the prevention and removal of shrinkage strains and stresses resulting from welding. The causes and effects of welding strains are generally known, but until recently very little definite information has been available concerning their prevention and removal. It is true that certain welding procedures and treatments were known to reduce or relieve welding strains, but quantitative data have not been available.

At the present time there are three recognized methods for reducing or eliminating residual welding strains or stresses:

(1) Proper design of the welded joints and structure.[1]
(2) Proper welding procedure and welding technique.[2]
(3) Annealing of the welded structure.

The first two methods deal with the prevention of welding strains during the process of welding, and are not capable of entirely eliminating such strains. They are very effective, however, in keeping the residual strains and stresses to a minimum. The third method deals with the removal of the welding strains after the work has been completed, and provided it is carried out properly, the residual welding stresses can be reduced to a few thousand lb./sq. in.

The effectivenes of annealing depends primarily upon two things: the annealing temperature and the soaking time (time the annealed article is held at the

[1] J. W. Owens, "Fundamentals of Welding," Chapter IX on Residual Stresses.

[2] Chas. H. Jennings, "The Effect of Welding Procedure on Shrinkage Strains in Butt Welded Joints." Journal of American Welding Soc., April, 1931, p. 27.

annealing temperature). It is the purpose of this paper to discuss the effect of three annealing temperatures and various soaking times on welding strains in welded structures. The annealing temperatures investigated were relatively low and did not cause grain refinement.

### Test Specimens

The design of the test specimen used in this investigation is shown in Fig. 1. The welding strains were induced in the specimens by welding the machined double vee in the center bar.

The rigidity of the specimen was such that the shrinkage strains from welding produced a maximum residual stress approximately equal to the yield point of the parent metal (30,000 lb./sq. in.).

The stress condition of the test specimens was such that the major portions of the three parallel bars

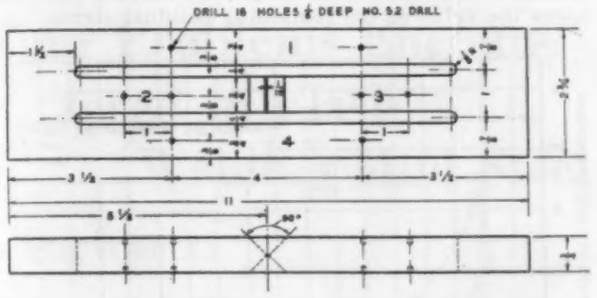



FIG. 1.—RESIDUAL STRESS PLATE

(see Fig. 1) were subject to approximately pure tension or compression. A bending moment was also present in the bars, but this moment was small and did not affect the results desired from the specimens.

The stress distribution at the ends of the bars (or slots) is complicated because of the stress concentration at those points. This stress condition, however, did not affect the results obtained from the specimens because all stress readings were taken at the center of the bars where the stresses were approximately uniform.

The specimens were made from hot-rolled low-carbon steel and were welded with 5/32-in. diameter uncoated electrodes, using about 140 amperes welding current. The same welding conditions and procedures were used on all the specimens, and it was found that the initial welding stresses were fairly uniform in all cases.

### Test Procedure and Results

The testing procedure consisted of three major operations: (1) welding the specimens, (2) annealing the specimens, and (3) making a saw cut through the welds after the specimens were annealed. Fig. 2 shows a photograph of a specimen before welding and a specimen after annealing and cutting.

Strain gage readings were taken between gage holes drilled on both sides of the specimens (see Fig. 2) before and after welding and before and after making the saw cut through the weld. A Berry strain gage with a 4-in. length was used to measure the strain at points 1 and 4 on the side bars, and the same gage with a 1-in. gage length was used to measure the strain at points 2 and 3 on the center bars.

All strain gage holes were reamed with a special reamer which produced a smooth radius at the edge of the holes (see Fig. 2). This improved type of hole made it possible to obtain an accuracy of 700 lb./sq. in. on a 4-in. gage length.

The relation between the strain readings taken on the center and side bars was found to agree very closely to the results that would be expected from the conditions of equilibrium of the specimens; i.e., the load and stress in the center bar was twice the loads and stresses in the side bars. As a result it was considered unnecessary to take both sets of readings. The center bar readings, therefore, were discontinued after several specimens had been tested.

The strain readings taken before and after welding gave data for computing the residual stress resulting from welding. Stress calculations were made by using the formula

$$S = Ee$$

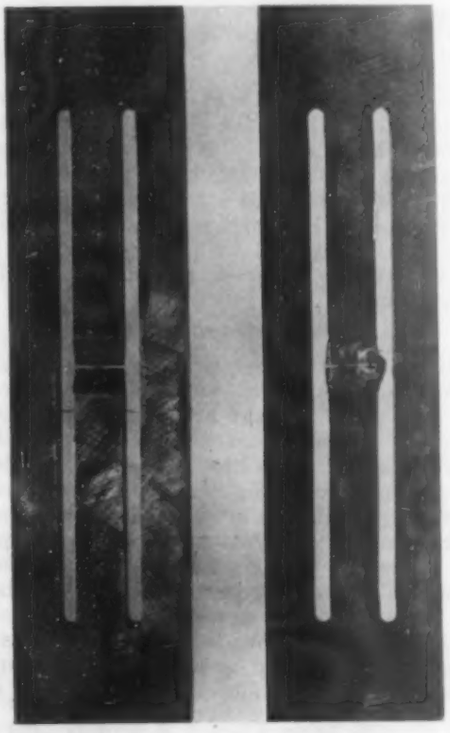
where S = stress in lb./sq. in.

E = modulus of elasticity.

e = measured unit elongation in inches.

The strain readings taken before and after making the saw cut through the annealed specimens gave data from which the stress remaining in the specimen after annealing could be computed. No correlation could be made between strain readings taken before and after annealing because of the plastic yielding in the specimens.

The annealing processes, which were carried out in a small electric annealing furnace, consisted of annealing the specimens at different temperatures and for different lengths of time. The small size of the test specimens and the annealing furnace made it possible to heat the specimens to the annealing temperature in 45 to 60 minutes. The annealing operations were completed by allowing the specimens to cool in



A B

Fig. 2—Residual Stress Plate

A Before welding
B After welding and cutting

the furnace. The test data taken on the specimens are tabulated in Table I.

TABLE I

| Spec. No. | Stress From Welding: Side Bars, (Comp.) Lb. per Sq. In. | Stress From Welding: *Center Bar, (Tens.) Lb. per Sq. In. | Stress After Annealing: Side Bars, (Comp.) Lb. per Sq. In. | Stress After Annealing: *Center Bar, (Tens.) Lb. per Sq. In. | Annealing Temperature, Deg. Fahr. | Soaking Time Hrs. per In. of Thickness |
|---|---|---|---|---|---|---|
| 1 | 13,800 | 27,600 | 2,900 | 5,800 | 1,000 | 1 |
| 2 | 14,600 | 29,200 | 2,980 | 5,960 | 1,000 | 1 |
| 3 | 14,200 | 28,400 | 3,110 | 6,220 | 1,000 | 1 |
| Ave. | | | | 5,990 | | |
| 7 | 15,000 | **30,000 | 940 | 1,880 | 1,000 | 2 |
| 8 | 14,700 | 29,400 | 1,300 | 2,600 | 1,000 | 2 |
| 9 | 15,200 | **30,000 | 1,500 | 3,000 | 1,000 | 2 |
| Ave. | | | | 2,490 | | |
| 10 | 14,300 | 28,600 | 1,880 | 3,760 | 1,000 | 1½ |
| 11 | 15,300 | **30,000 | 1,760 | 3,520 | 1,000 | 1½ |
| 12 | 15,600 | **30,000 | 1,690 | 3,380 | 1,000 | 1½ |
| Ave. | | | | 3,550 | | |
| 13 | 14,150 | 28,300 | 4,840 | 9,680 | 1,000 | ½ |
| 14 | 15,450 | **30,000 | 4,500 | 9,000 | 1,000 | ½ |
| 15 | 15,300 | **30,000 | 4,120 | 8,240 | 1,000 | ½ |
| Ave. | | | | 8,970 | | |
| 29 | 15,200 | **30,000 | 7,090 | 14,180 | 1,000 | 1/16 |
| 20 | 13,200 | 26,400 | 940 | 1,880 | 1,100 | 1½ |
| 21 | 13,700 | 27,400 | 1,050 | 2,100 | 1,100 | 1½ |
| 22 | 14,500 | 29,000 | 940 | 1,880 | 1,100 | 1½ |
| Ave. | | | | 1,950 | | |
| 23 | 14,600 | 29,200 | 1,610 | 3,220 | 1,100 | 1 |
| 24 | 14,800 | 29,600 | 1,840 | 3,680 | 1,100 | 1 |
| 25 | 14,900 | 29,800 | 1,610 | 3,220 | 1,100 | 1 |
| Ave. | | | | 3,370 | | |
| 26 | 14,500 | 29,000 | 3,110 | 6,220 | 1,100 | ½ |
| 27 | 14,400 | 28,800 | 3,040 | 6,080 | 1,100 | ½ |
| 28 | 14,800 | 29,600 | 3,100 | 6,200 | 1,100 | ½ |
| Ave. | | | | 6,170 | | |
| 30 | 14,600 | 29,200 | 5,440 | 10,880 | 1,100 | 1/16 |
| 4 | 14,500 | 29,000 | 1,110 | 2,220 | 1,200 | 1 |
| 5 | 14,100 | 28,200 | 1,260 | 2,520 | 1,200 | 1 |
| 6 | 15,700 | **30,000 | 760 | 1,520 | 1,200 | 1 |
| Ave. | | | | 2,090 | | |
| 16 | 14,700 | 29,400 | 1,760 | 3,520 | 1,200 | ½ |
| 18 | 13,610 | 27,220 | 2,150 | 4,300 | 1,200 | ½ |
| 19 | 14,200 | 28,400 | 1,610 | 3,220 | 1,200 | ½ |
| Ave. | | | | 3,680 | | |
| 17 | 14,800 | 29,600 | 4,000 | 8,000 | 1,200 | 1/16 |

*Stress in center bar (see Fig. 1) is taken as two times the stress measured in the side bars.

**Maximum stress in center bar (see Fig. 1) is taken as the yield point of the material (30,000 lb./sq. in.).

Curves plotted from these data are shown in Fig. 3. The ordinate of the curves is soaking time in hours per inch of thickness of the plate and the abscissa is the residual stress remaining in the specimen after annealing. The residual stress values obtained with soaking times of 1/16 hrs. per inch of thickness (see Fig. 3) agree very well with the yield point stresses of the material as obtained from short time high-temperature tests.

## Discussion of Results

In discussing the test results, it is advisable to first mention the theory underlying the process of strain annealing. Strain annealing is a method of eliminating residual stresses in a structure by subjecting the structure to high temperatures and is dependent upon three things: (1) within certain limits of strain a ductile metal will not develop a stress greater than its yield point, (2) the yield point of metals decreases at high temperatures, and (3) the phenomenon of creep or plastic flow at high temperatures[3,4] takes place.

The action of the above items during the annealing process is best explained by an example. Assume first a welded structure which contains residual stresses close to the yield point of the parent metal. In order to relieve these residual stresses, the structure may be annealed, let us say, at 1100 deg. Fahr.

As the temperature of the structure increases, the yield point of the material decreases. Also because the metal will not maintain a stress greater than its yield point (provided the amount of plastic strains is small) the residual stress will also decrease. When the temperature of the structure reaches 1100 deg. Fahr., the remaining residual stress will be approximately 12,000 lb./sq. in. See Fig. 3.

If the structure were to be cooled uniformly immediately after reaching this temperature, the resultant final residual stress would be 12,000 lb./sq. in. If, however, instead of cooling the specimen immediately after it reached the annealing temperature, it is allowed to soak at that temperature, the phenomenon of creep comes into play and the metal flows or creeps, thus further reducing the residual stress. See Fig. 3. Within certain limits, the longer the soaking time, the lower the value of the remaining residual stress.

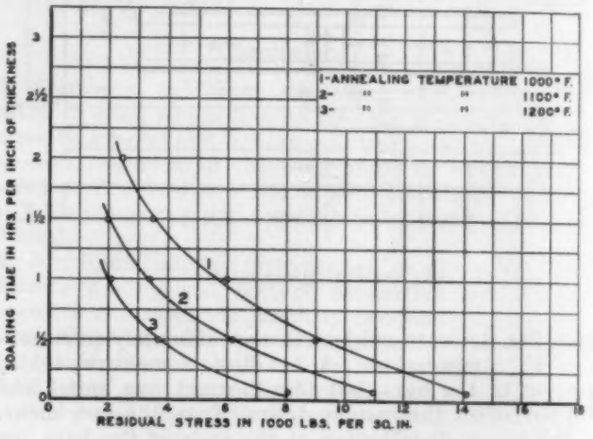



Fig. 3—Soaking Time—Stress Curve

Keeping the above discussion in mind, it is seen that the soaking time-stress curves (Fig. 3) give the soaking time necessary in conjunction with a given annealing temperature to reduce the final residual stresses in a structure to a given minimum value.

The maximum allowable residual stress in a structure and the annealing temperature will often depend upon the article itself and the facilities for annealing. It should be borne in mind, however, that the higher the annealing temperature, the greater is the possibility of warping. As a result, in some cases it might be advisable to anneal a structure at 1000 deg. Fahr. and allowing it to soak for 1½ hours per inch of thickness in order to reduce the stress to 3000 lb./sq. in., rather than to anneal it at 1200 deg. Fahr. and allow it to soak for about ½ hour per inch of thickness.

When strain annealing it is not essential that the yielding take place in the welds. Yielding of the parent metal is just as effective in relieving residual stresses.

It is also well to mention that the test specimens were annealed under laboratory conditions and that the time expended in heating and cooling the specimens was relatively small. In production where the annealing furnaces are large and the temperature changes slow, the heating and cooling cycles may in effect increase the soaking time. This factor, however, is on the safe side and induces an added factor

[3] P. G. McVetty, "Creep of Metals at Elevated Temperatures." Mechanical Engineering, Vol. 53, No. 3, p. 197.

[4] J. J. Kanter and L. W. Spring, "Long-Time or Flow Tests of Carbon Steels at Various Temperatures with Particular Reference to Stresses Below the Proportional Limit." Proc. A.S.T.M. Vol. 28, Part II, p. 80.

of safety in that the resultant stresses will be below the values given by the curves in Fig. 3.

The results of this investigation were obtained from specimens stressed in direct tension and compression. The possibility of obtaining different results with specimens subjected to bending stresses is recognized and will warrant further investigation.

### Conclusions

From the results of these tests the following conclusions on strain annealing welded low-carbon steel structures can be drawn.

1. Welding strains and residual stresses can be reduced by annealing at temperatures below the critical point of the material.

2. The effectiveness of annealing in reducing welding strains depends upon the annealing temperature and the soaking time.

3. In order to obtain a given minimum residual stress, the higher the annealing temperature, the shorter the soaking time required.

4. By proper annealing, residual stresses in welded structures can be reduced to a few thousand pounds per square inch.

### Acknowledgments

The writer wishes to give special acknowledgment to Messrs. R. E. Peterson and P. G. McVetty for valuable suggestions in preparing this paper.

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# Four Problems Encountered in Flash Welding Mild Steel

*By* E. R. TORGLER

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by E. R. Torgler, Metallurgist, S. R. Dresser Mfg. Co.

This paper was submitted by the author as a thesis to Case School of Applied Science, Cleveland, Ohio, in May, 1931, for the Degree of Metallurgical Engineer (Met. E.)

ELECTRICAL Resistance Flash Welding, commonly called "Flash Welding," is most certainly one of the outstanding prodigies of modern industry. It is a method of permanently, effectively and cheaply joining metallic parts at a rate entirely in step with modern mass production methods. Flash welds are exceedingly reliable; the welds are almost always as strong as the metal welded; and perhaps no other method of welding lends itself so readily to the repetitive processes found in manufacturing plants where metals are fabricated.

Although a great many industries have already taken advantage of the economies in material, weight, and manufacturing costs afforded by flash welding, the field of application seems hardly to have been scratched, and I believe we can safely predict a decided increase in the number of applications for many years to come.

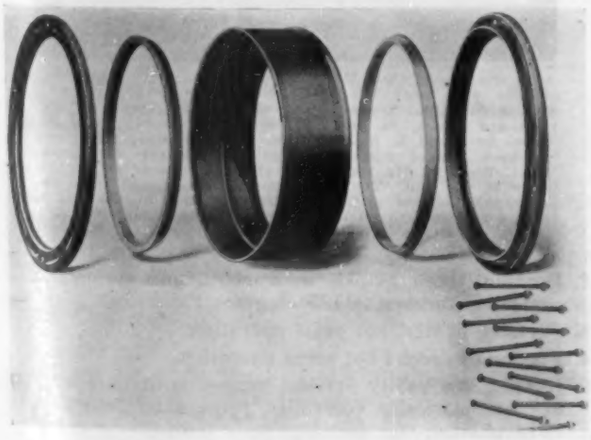


Fig. 1

In addition to this increase in the number of applications, it is also reasonable to expect many improvements in the process itself and these improvements should further broaden the field of application. This is true of all new processes.

Each application presents its own particular problems. A few of these problems, however, are of a general nature and may be applied in a large number of cases. The following four problems were encountered in the flash welding of mild steel middle rings for Dresser Pipe Couplings and the solutions are offered as points of general interest to those who are concerned with the application and the development of the process.

Before taking up the individual problems in detail, a description of Dresser Pipe Couplings will clarify the application of the solutions for the reader.

Dresser couplings are standard flexible pipe joints without threads and are made in all standard pipe sizes, both steel and cast iron, from ⅜ in. to 72 in. in diameter. They are composed of a flared middle ring, two wedge shaped gaskets of a special rubber compound, two follower rings or flanges, and a number of bolts, the number depending on the size of the coupling. Fig. 1 shows the parts of a 24-in. diameter coupling. The method of manufacture is not the same for all sizes, but in this paper we shall consider only the method used in the manufacture of from 8-in. diameter to 26-in. diameter couplings, inclusive.

### Middle Ring

The middle rings are made from mild steel bar stock which is rolled in the special Dresser sections by The Carnegie Steel Company. These sections are shown in the Carnegie Shape Book. The widths are either 5 in., 7 in., 8 in. or 10 in. and the thicknesses ¼ in., 5/16 in., 11/32 in., ⅜ in. and ½ in., depending on the size of the coupling and the pressure in the line to be coupled. The steps in the manufacturing process are as follows:

1. Cold shearing of the bar steel to the correct length.
2. Cold rolling of the sheared lengths to the desired diameter.
3. Flash Welding. This is done on flash welding machines very similar to those used in the flash welding of automobile tire rims. However, the requirements for a middle ring weld are much more exacting than for a

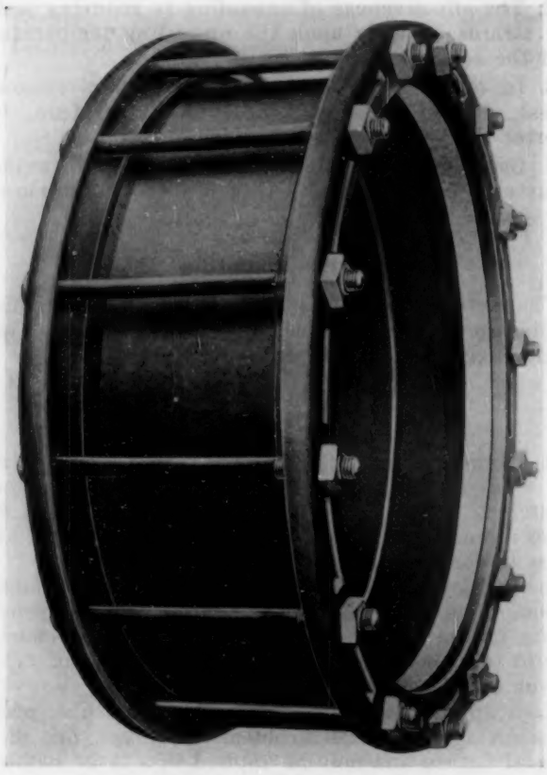


Fig. 2—An Assembled Dresser Coupling

weld in an automobile tire rim. A middle ring weld must not only be stronger but it must be absolutely non-porous. The working pressure on a coupling is applied from within the pipe line and when in service, the weld is under tension. The weld in a tire rim is practically never under tension. The welding cycle is automatic.

4. Cooling of the flash welds. The rings are run through a water spray as they come from the flash welders in order to cool the metal before chipping the flash from the welds. The metal tears if it is chipped hot and is much more difficult to handle.
5. Chipping the flash from the welds. The flash is removed by pneumatic chipping chisels or by a flash shearing machine of special design. The inside of the weld is chipped flush with the inside circumference of the ring while a small ridge of upset metal is left on the outside of the ring to give added strength to the weld.

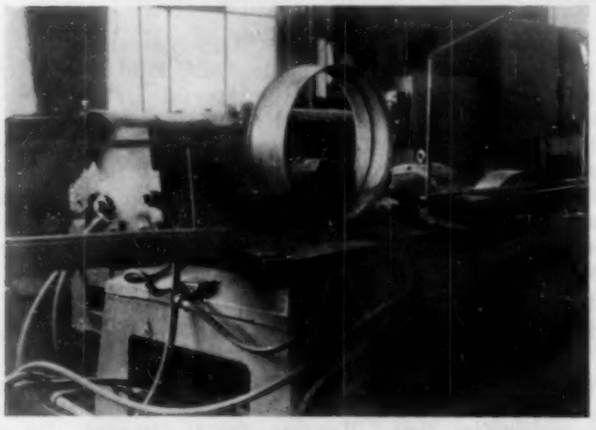


Fig. 3—Photograph of Typical Flash Welding Machine Used in the Dresser Plant

6. Grinding the inside of the flare at the weld. This is done to insure a smooth surface for the wedge shaped rubber gaskets.
7. External cold sizing. The rings are placed between two semi-circular dies and pressed to the desired outside diameter.
8. Internal cold sizing. The desired inside diameter is obtained by forcing hardened tool steel plugs into the rings in a bulldozing press especially designed for the purpose.
9. Testing the welds for leaks. The rings are clamped between two rubber discs and 90 lb. air pressure is applied inside the ring while the outside of the weld is painted with a soap solution. Any defects in the welds are thus very easily detected.
10. Cleaning loose mill scale from both the inside and the outside of the tested rings. This is done with a wire buffing wheel on a portable grinder.
11. Final inspection. At this point in the process the rings are thoroughly inspected for defects in material and in workmanship, and if any defects are found the rings are either scrapped or sent back to the appropriate point in the production line for repairing.
12. Drying. The rings are then run through a small drying oven to remove all traces of moisture.
13. Application of rust-proof coating. The specified rust-proof shop coating is applied by painting, dipping, or spraying and the rings are then hung on the overhead conveyor which takes them to the car or to the stock piles.

## Flanges

The flanges are hot press formed from low carbon plate steel of thicknesses of ¼ in., 5/16 in., 11/32 in. and ⅜ in. The steps in this process are:

1. Cold blanking the steel plate into "doughnut" shaped rings.

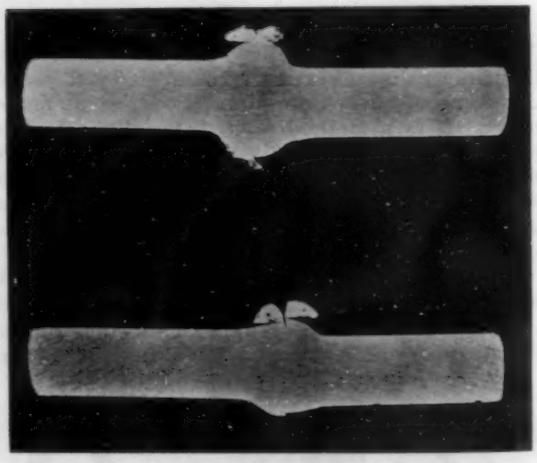


Fig. 4

Photomicrograph. The section at the top illustrates the ¾ in. burn and the ⅜ in. jam. The lower section illustrates the ¼ in. burn and ⅛ in. jam. The flash or burned metal has not been chipped from these sections. The ears of burned metal (flash) on the upper sides of these sections are on the inside of the ring. The burned metal has dropped from the lower sides of the sections (outside surfaces of the rings) because this surface was down during the welding. The difference in metal consumed is apparent

2. Heating these blanks in a continuous automatically controlled furnace to 1850 degrees Fahrenheit.
3. Forming or first hot press operation.
4. Flaring or second hot press operation.
5. Heating the partly finished flanges in another continuous automatically controlled furnace to 2000 degrees Fahrenheit.
6. Belling or final hot press operation.

Fig. 5

Photomicrograph. Section through the line of weld where 5/8 in. burn and 5/8 in. jam were used. The finer grains running from top to bottom of the photograph are in the line of weld but no fine line is apparent and the weld is complete without undue distortion of the grains. The steel itself was a little dirty as evidenced by the sonims, which, however, are not segregated and do not seem to have had any effect on the welding

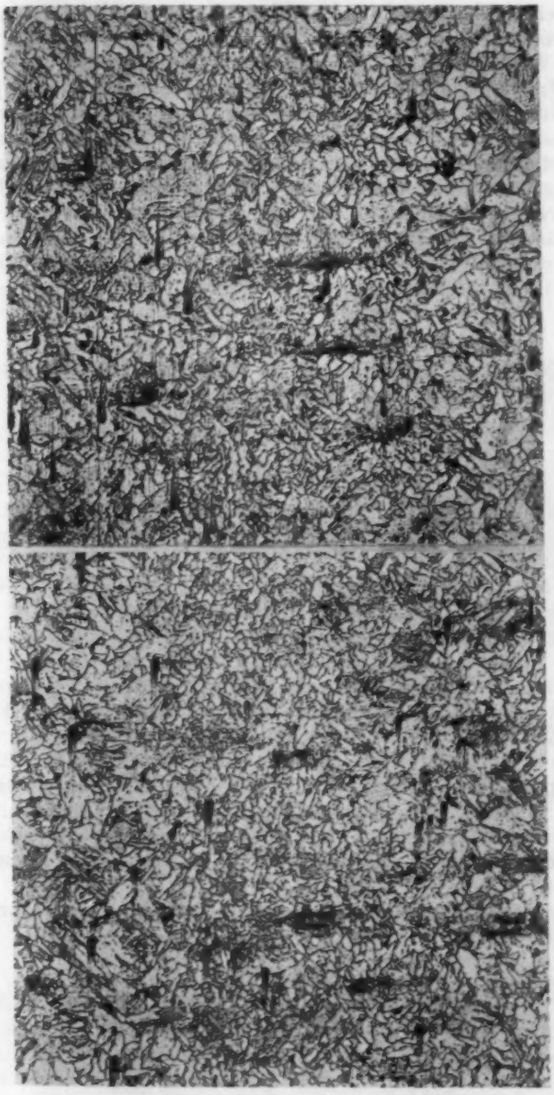


Fig. 6

Photomicrograph. This illustrates the structure through the line of weld where 1/4 in. burn and 1/4 in. jam were used. Again there is no fine line of weld but the fine grains running from top to bottom of the photograph show where the union has taken place. This weld is just as complete as the one illustrated in Fig. 5, and the grains, if there is any difference, are a little finer. We would expect this weld to be slightly stronger. Both photomicrographs were taken at 100 magnifications

7. Heat treating. The hot flanges from the belling press are quenched in cold water which treatment toughens them materially.
8. Bolt holing. The bolt holes are punched cold, using a soap solution for a lubricant.
9. Cleaning. The loose mill scale is brushed from the flanges in the same manner that it is removed from the middle rings.
10. Inspection. Each flange is carefully inspected for defects in material and workmanship.
11. Protective coating. The specified rust-proof shop coatings are applied by painting, dipping or spraying, after which the finished flanges are hauled on industrial railroad trucks to the cars or to the stock piles.

### Bolts

The special Dresser track head bolts are made by a number of well-known bolt companies. These bolts are purchased under rigid specifications covering chemical analysis, physical properties and mechanical tolerances.

### Gaskets

Dresser gaskets are made by three large rubber companies. The rubber compounds used were developed especially for pipe line service. A number of different compounds are used, the recommendation depending on the nature of the substance the pipe line is to carry. These recommendations are backed by many years of experience with pipe line installations and by data gathered from special test lines where accelerated tests are continually being made on all types of gaskets which are submitted for the approval of the engineering department.

The following four problems refer only to

## Middle Ring

## PROBLEM NO. 1

## SUBJECT: THE DETERMINATION OF THE NECESSARY FLASH AND UPSET (BURN AND JAM) FOR A SATISFACTORY MIDDLE RING FLASH WELD.

### Occasion

It was desired to determine whether a saving in metal might be affected by decreasing the amount of burn and jam in our regular flash welds. The regular practice was a 3/8-in. burn and a 3/8-in. jam on 3/8-in. steel. At the time the question arose we were making 22-in. diameter middle rings from 3/8-in. x 7-in. bar steel, so it was decided to investigate the welds on this section first in order to come to some tentative conclusion as soon as possible and, later, to check these results by a similar investigation of welds made on our other standard sections.

As a certain amount of upset metal was desirable on the outside of the finished rings we did not think it practical to decrease the jam to less than 1/4 in. Accordingly, a jam of 1/4 in. was decided upon as the minimum. If we were able to make acceptable welds using a 1/4-in. burn and a 1/4-in. jam, we would affect a maximum saving. If this were not practical, we would try a burn and jam somewhere between 3/8 in. and 1/4 in.

The welding machines were installed exactly as recommended by the manufacturer and no attempt was made to change this installation in any respect.

If we were able to successfully adopt the 1/4-in. burn and 1/4-in. jam we would save 0.186 lb. of steel per weld or about 558 lb. of steel for every 3000 middle rings. In addition to this there would be an increase in production from the welding machines due to the decreased welding time and there would be less flash to be chipped from the welds.

### Procedure

Ten 22-in. middle rings were welded using 1/4-in. burn and 1/4-in. jam. The welds were chipped and carefully inspected on both the inside and outside surfaces. No surface defects were observed. Two of

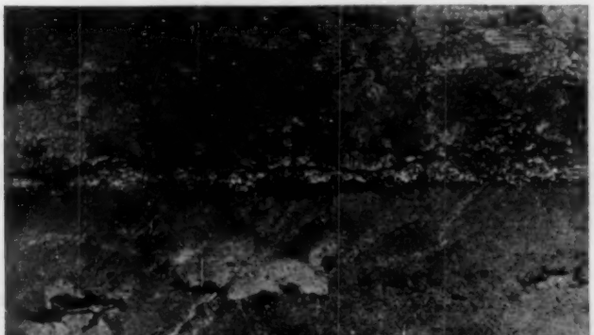


Fig. 7

Photomicrograph. 2½ in. diameters. Showing the pitted surface of the chipped weld. The photograph was taken of the outside surface of the middle ring. Note that the pits occur on either side of the line of weld as in the line of weld and that they are irregular in size and shape

these rings were selected at random and from each ring two sections were cut, at right angles to and including the weld, one for macro and one for micro examination. The sections were taken about half way between the outside edge of the flare and the center rib. At the same time two rings were selected at random from the regular production where the ⅜-in. burn and ⅜-in. jam had been used and similar sections were cut for macro and micro examination. One section from each ring was polished and etched in 5 per cent nital for microscopic examination and one section from each ring was rough polished and macro-etched in a hot 50 per cent colution of hydrochloric acid.

### Results

The macro-etched sections showed clearly the difference in metal consumed in the two welding procedures. No defects in the line of weld were noted. There was a noticeable banding in the steel which is common to all hot rolled sections and at the welds where the metal was upset there appeared to be a marked tendency for the bands to separate slightly, due to the upsetting or jamming. In other words, the metal which had been upset appeared to be less dense than the parent metal which had not been heated in the welding operation. Where the ¼-in. jam had been used the apparent separation of the bands was less pronounced. From this it was a reasonable assumption that if the upsetting was responsible for a decrease in the density of the metal at the weld we might expect this effect to be less marked where the upsetting was cut down to a minimum.

The microscope revealed very little difference between the sections illustrating the ¼-in. burn and jam and the sections illustrating the ⅜-in. burn and jam. The polished sections all showed complete union of the grains at the line of weld and no excessive grain growth where the heating effect was most pronounced. The sections illustrating the ¼-in. burn and jam appeared to be slightly finer grained throughout, which is an indication of a stronger weld, but the difference was very slight.

### Conclusions

The above seemed to be conclusive proof, so far as could be determined by the microscope and the macro-etched sections, that we could safely adopt the ¼-in. burn and ¼-in. jam when welding ⅜-in. x 7-in. steel. If there were any difference in the quality of the welds it seemed to be in favor of the smaller burn and jam.

We adopted the ¼-in. burn and jam for the ⅜-in. x 7-in. steel at once and did not run into any trouble with the welds even though they were inspected much more thoroughly than before. This, as pointed out in a foregoing paragraph, has the maximum saving we could make and still produce welds which were acceptable to our inspection department so it was not necessary to experiment further. We later decreased the burn and jam used on all sizes of steel without running into any difficulty.

## PROBLEM NO. 2

## SECONDARY PIPING AND SEGREGATED IMPURITIES AS CAUSES OF DEFECTIVE FLASH WELDS

### Occasion

One of the first problems called to my attention at the Dresser plant was the occurrence in the flash welding department, at not infrequent intervals, of welds which when chipped exhibited decidely pitted surfaces. The pits did not always occur directly in the line of weld. Sometimes they were found as far as ¼ in. to either side.

The welders complained that something was wrong with the steel as they would run along for several days with comparatively few bad welds and all at once as high as 20 per cent defective welds would appear for a short period with absolutely no change in the welding operation. Other men in the department felt that some change in the welding operation had been made and that the welders were not aware of it.

A great many of the defective welds were beyond repair.

### Procedure

A typical pitted weld in a 22-in. diameter middle ring made of ⅜-in. x 7-in. steel was selected. The appearance of this weld when chipped is shown in Fig. 7. A section for microscopic examination was cut at right angles to the weld about half way between the outside of the flare and the center rib. The section was polished and etched in 5 per cent nital and

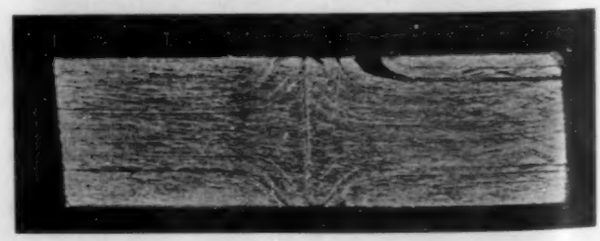


Fig. 8

Photomicrograph. 2½ in. diameters. Specimen etched in 50 per cent hydrochloric acid. The large pit on the upper surface to the right of the weld is practically a lamination. The smaller pits are plainly the ends of less pronounced lines of impurities. This section shows the effect of the upsetting. It is obvious that the greater the upsetting or jam, the more lines of impurities will be forced to the surface. The line of weld shows very plainly under the macro-etch but it does not show under the microscope. Where the impurities are absent the weld is complete

six photomicrographs were taken to illustrate the different zones of the weld and the occurrence of the pits which were causing the trouble. The same section was then macro-etched in a 50 per cent solution of hydrochloric acid and is shown in Fig. No. 8.

### Conclusions

The photographs, which trace the lines of impurities from the parent metal to the line of weld, are self-explanatory. They show rather conclusively that the pits were due to the presence of the impurities which were segregated in rather narrow lines in the direction of rolling. These lines showed a tendency to part where they came to the surface due to the upsetting. In some cases, where the larger pits occurred, the impurities were so numerous that the lines resembled laminations rather than just segregations.

I was of the opinion that we were either getting dirty steel or that the steel mill was not cropping enough off the ingots. Prior to this investigation a number of men from the steel mill had visited our plant on this very problem, but they all reported that they believed the trouble to be due to some unknown variation in our welding process and not due to any variation in the steel. When my report was completed we called in representatives from the steel company and they agreed that the steel was at fault. They promised to investigate the matter thoroughly at the mill with the result that we have encountered no more pitted welds, although my report was dated Oct. 27, 1929.

Aside from their relation to the pitted welds, these photomicrographs are of unusual interest because they show very plainly the effect of the heating during the welding operation on the adjacent metal. Beginning at the line of weld and moving either right or left at right angles to it we find three distinct zones which were produced by the welding and which

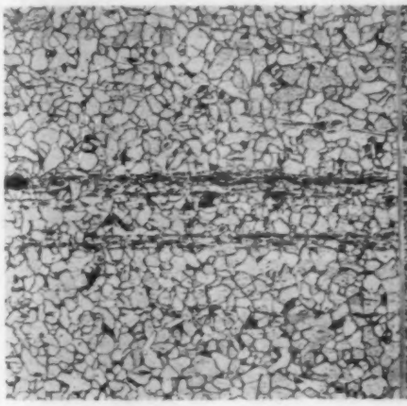


**Fig. 9**

Photomicrograph. 100 diameters. This shows the most pronounced line of impurities (the line ending in the largest pit, photomicrograph No. 2, upper surface to the right of the line of weld) in the parent metal where the structure has not been affected by the welding. This is a typical low carbon hot rolled section

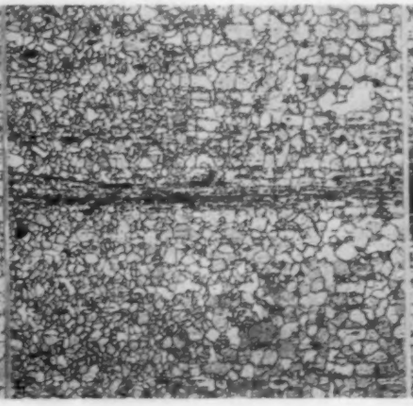


**Fig. 10**

Photomicrograph. 100 diameters. This shows the same line of impurities as it approaches the weld. The finer grains at the left are nearer the weld and show the grain refinement produced by the upsetting. This photomicrograph was taken approximately ¼ in. from the line of weld. The refined grains are not badly distorted and indicate hot work slightly above the critical temperature

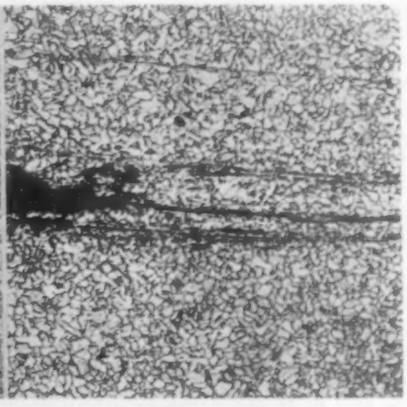


**Fig. 11**

Photomicrograph. 100 diameters. This shows the same line of impurities where it parted the steel and produced the large surface pit. This photomicrograph was taken about 3/16 in. from the line of weld. Note that the grains toward the left, as we approach the line of weld, are increasing in size

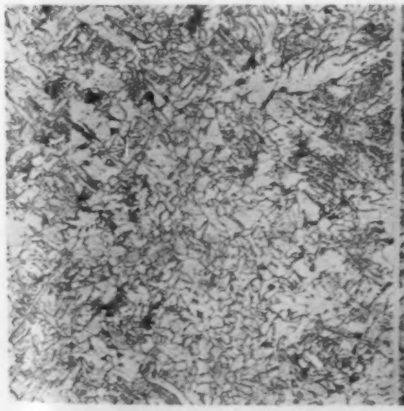


**Fig. 12**

Photomicrograph. 100 diameters. Section through the line of weld showing that where the impurities are not segregated or are not present the weld is complete without defect. The line of weld is in the zone of smaller grains running from top to bottom of the photomicrograph. As we approach the line of weld from the refined grain zone shown in the preceding photomicrographs, the grains are progressively larger, due to the increasing effect of the heating, until right at the line of weld we find another zone of refined grains

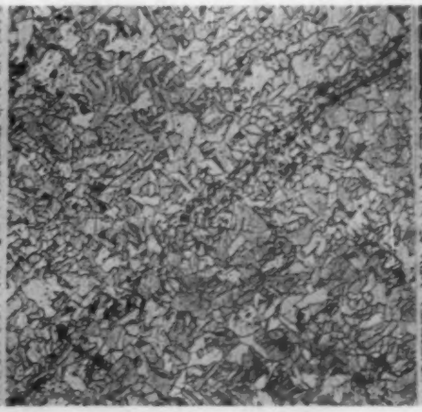


**Fig. 13**

Photomicrograph. 100 diameters. Showing another line of segregated impurities very near the weld, just before it reaches the surface

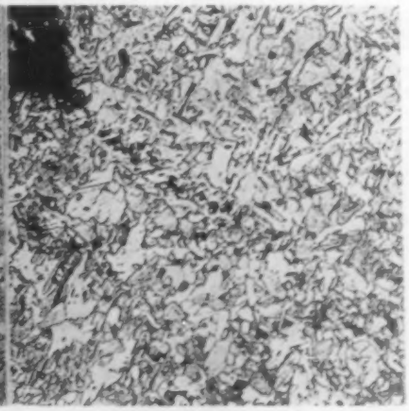


**Fig. 14**

Photomicrograph. 100 diameters. Showing the same line of impurities as Fig. 13, where it reaches the surface. This is in the zone of grain enlargement near the line of weld

**Fig. 15**

Photomicrograph. Natural size. The three specimens on the left show the roll weld and the two on the right the flash weld. Note that on the three specimens illustrating the roll weld the line of weld is very plain while the flash welded specimens show no line of weld and exhibit a uniform surface throughout. All five specimens were prepared in exactly the same manner. The specimen to the right shows the weld after chipping, while the second from the right shows the upset metal before chipping

blend into each other. At and in the immediate vicinity of the line of weld we find a rather narrow zone of fine grains where the refining effect of the upsetting more than offset the tendency to grain growth produced by the welding heat. This zone blends into another comparatively wider zone of enlarged grains where the tendency of the grains to grow predominated. This we would expect to be the weakest section of the weld. These enlarged gains grade into another zone where the grains have been refined due to the upsetting, as shown in Figs. No. 2 and No. 3. This third zone is next to the parent metal.

The reader will probably notice that in Fig. No. 4 the grains at the weld are considerably larger than the grains shown in the photomicrographs under problem No. 1. This is accounted for by fact that the welds shown in Problem No. 2 were made before the welds in Problem No. 1, and before the burn and jam had been cut down to a minimum.

## PROBLEM NO. 3

## SUBJECT: A COMPARISON BETWEEN A FLASH WELD AND A ROLL WELD ON THE SAME SIZE MIDDLE RING.

### Occasion

When we were considering the installation of a new middle ring department, along with a number of other additions, to increase the capacity of the Dresser plant the question of roll welding versus flash welding was discussed at length. We knew of one plant where they were roll welding middle rings of a section quite similar to the Dresser sections and we were all interested in determining the relative merits of the two methods before deciding on new equipment.

The roll welds were made, we had been told, by rolling the entire rings over a mandrel after they had been heated to the welding temperature, the ends having been lapped before rolling.

### Procedure

We secured a 20-in. diameter roll welded middle ring made of 5/16-in. thick steel. We then selected a Dresser flash welded ring of the same diameter and cross section. Three sections were cut at right angles to the roll weld about half way between the outside edge and the center rib. The three sections included the entire weld, that is, when laid end to end they made up a complete cross section. Two similar sections were cut from the flash welded ring at right angles to and including the weld. All five specimens were polished and etched in 5 per cent nital. The following five photographs with their legends show the results.

### Conclusion

The photomicrographs are quite strong evidence in favor of the flash weld. With a decidedly better union of grains at the line of weld, with the absence of inclusions at or near the line of weld, and with a much finer grain structure throughout, our natural conclusion was that the flash weld is more effective and more satisfactory, from the standpoint of performance, than the roll weld. We would expect the flash weld to be stronger and more ductile.

However, we must not lose sight of the fact that we have only examined one roll weld. All roll welds might not give such bad accounts of themselves, although there is no reason to suppose the weld we examined not to be a typical one. Also, in considering the probable comparative tensile strength of the two welds, we must remember that the line of weld in the roll weld was a little over 2 in. long, due to the lapping, while the line of weld in the flash weld is only

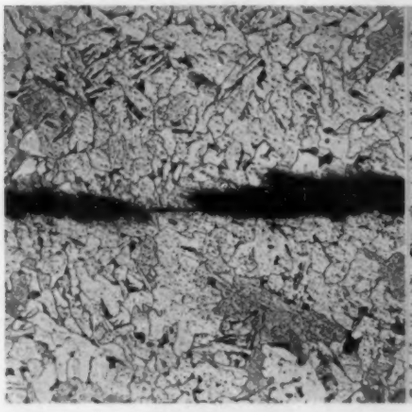


**Fig. 16**

Photomicrograph. 100 diameters. Section of roll weld showing a void where there is no union of metal probably due to pocketed gas. Note the very large grains which are the result of excessive heating

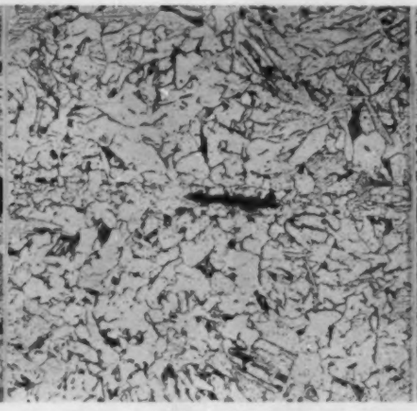


**Fig. 17**

Photomicrograph. 100 diameters. Showing another section of the roll weld. The elongated black particle in the center is probably flux slag in the line of weld. On both sides of this inclusion there is a union of the grains but the line of weld is plainly visible. The enlarged grains are still in evidence

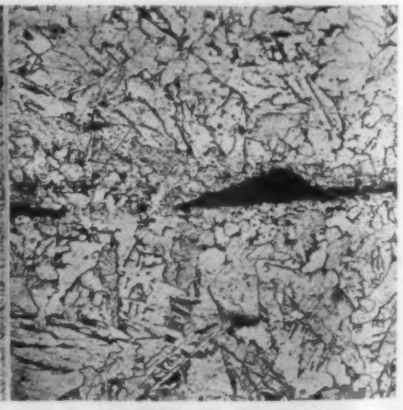


**Fig. 18**

Photomicrograph. 100 diameters. Showing still larger flux slag inclusions along the line of weld in the roll weld. The grains in this case are even larger than in the other two photomicrographs of the same weld. The line of weld is plainly visible even where there are no slag inclusions

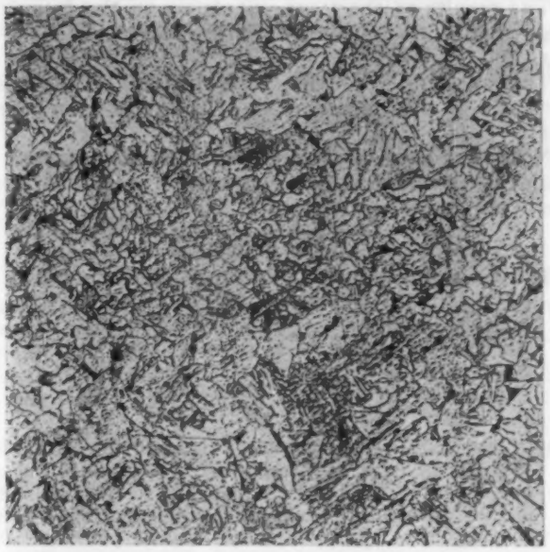


Fig. 19
Photomicrograph. 100 diameters. Showing the line of weld of the flash weld. Note the more complete union of the grains, the absence of a well defined line of weld, and the finer grain structure

as long as the thickness of the metal welded plus the amount of upset metal which remains after chipping. Even though the line of weld in the roll weld is interrupted by voids and by flux slag inclusions the sum of the areas where these interruptions do not occur may be great enough so that a tensile bar cut at right angles to the weld would not fail through the weld itself.

On the other hand, from this evidence and from our knowledge of the two welding processes we would expect voids, slag inclusions, and enlarged grains in any roll weld, while we would expect the flash welds to be cleaner and finer grained. The finer and cleaner structure is always the more desirable from the standpoints of tensile strength, ductility, and also resistance to corrosion.

We were satisfied that the roll weld was not to be considered further.

## PROBLEM NO. 4

**SUBJECT: TENSILE TESTS OF MIDDLE RING FORMED SKELP BEFORE PROCESSING. AT DIFFERENT POINTS DURING THE PROCESSING, AND AFTER PROCESSING IN OUR FLASH WELD DEPARTMENT.**

### Occasion

As explained before, the flash welded middle rings, while they are being fabricated, are subjected to rather severe cold working when they are bent and later cold sized both externally and internally. We expected that this cold working increased the tensile strength and the yield point of the steel with a corresponding loss in ductility and were therefore desirous of determining the extent of this cold working effect.

### Procedure

We arranged to have all the tensile tests made at Case School in the Department of Mechanics & Hydraulics.

We were working on quite a large order of 24-in. diameter x ⅜-in. x 7-in. middle rings so it was decided to use these rings for the tests.

As most of the tests would have to be made on test bars prepared from finished or partly finished rings we first considered the possibility of using, as test bars, complete circular sections of the rings to be tested, milled to a uniform width. Professor Danforth, head of the Department of Mechanics and Hydraulics at Case School, was consulted in the matter and he explained that we could make such tests providing we first made special yokes and mandrels according to the sketches he submitted. (We later made the special yokes and mandrels as Professor Danforth suggested and found them very satisfactory for testing the welds in 24-in. middle rings. These tests are more favorable to the weld than the tests described below.) This would mean considerable delay in obtaining the desired information so the test bars were prepared as follows:

Eighteen-inch sections, including the entire width, were cut from the rings with an acetylene torch. Where it was desired to test the welds, the sections were cut with the weld at the center. The sections were then flattened between special plates in a hydraulic press. The test bars were milled from the flattened sections and were all cut next to the center rib of the ring.

Thirty-six coupons were prepared as follows:

Nos. 1 to 4 inclusive—Taken from the bar steel as it comes from the steel mill.

Nos. 5 to 13 inclusive—Taken from the rings after they had been cold rolled and welded but not chipped. Nos. 5, 9, 10 and 11 were outside the weld, while Nos. 7, 8, 12 and 13 included the weld.

Nos. 14 to 21 inclusive—Taken from rings which had been cold rolled, welded and chipped. Nos. 14, 15, 18 and 19 were outside the weld and Nos. 16, 17, 20 and 21 included the weld.

Nos. 22 to 29 inclusive—Taken from rings which had been cold rolled, welded, chipped and cold sized. Nos. 22, 23, 26 and 27 were outside the weld, while Nos. 24, 25, 28 and 29 included the weld.

Nos. 30 to 37 inclusive—Taken from finished rings which had been cold rolled, welded, chipped and cold sized. The welds in these rings had been sprayed with cold water as they came from the welding machines. Nos. 30, 31, 34 and 35 were outside the weld, while Nos. 32, 33, 36 and 37 included the weld.

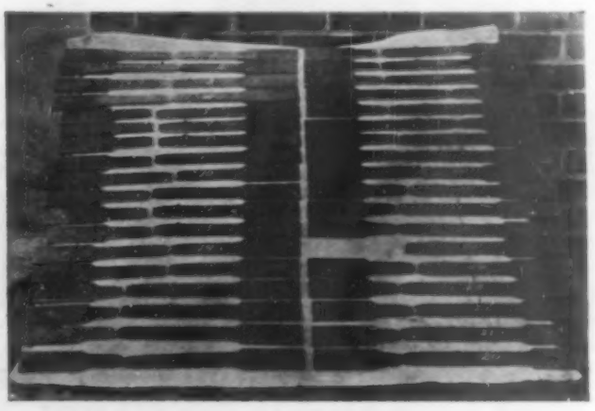


Fig. 20
Photograph of the test bars described under Problem No. 4. The welds are easily discernible including the one in the bar which failed in the weld i.e. No. 29

| Bar No. | Yield Point, Lb./Sq. In. | Ultimate Strength, Lb./Sq. In. | Per Cent Elongation 8 In. | Per Cent Reduction of Area | |
|---|---|---|---|---|---|
| 1 | 29,830 | 45,500 | 33.2 | 65.6 | |
| 2 | 29,750 | 45,500 | 33.3 | 65.2 | |
| 3 | 29,880 | 45,800 | 34.8 | 65.8 | |
| 4 | 29,650 | 45,700 | 34.4 | 65.6 | |
| 5 | 30,900 | 47,700 | 30.5 | 65.2 | |
| 9 | ..... | 48,500 | 26.8 | 64.9 | |
| 7 | 31,300 | 48,600 | 23.5 | 56.5 | Welded |
| 8 | 31,550 | 48,900 | 21.6 | 62.1 | Welded |
| 10 | 30,940 | 48,350 | 29.7 | 64.8 | |
| 11 | 31,460 | 49,000 | 27.7 | 63.4 | |
| 12 | 30,540 | 49,350 | 20.5 | 56.2 | Welded |
| 13 | 30,820 | 49,000 | 19.6 | 63.3 | Welded |
| 14 | 30,330 | 48,400 | 28.4 | 63.7 | |
| 15 | 31,310 | 49,250 | 24.0 | 58.7 | |
| 16 | 31,550 | 50,100 | 18.1 | 57.1 | Welded |
| 17 | 31,230 | 49,400 | 22.8 | 58.0 | Welded |
| 18 | 30,430 | 48,600 | 27.8 | 64.8 | |
| 19 | 30,110 | 49,000 | 22.2 | 64.8 | |
| 20 | 31,140 | 49,200 | 21.0 | 62.5 | Welded |
| 21 | 31,540 | 49,400 | 20.8 | 57.9 | Welded |
| 22 | 31,560 | 49,500 | 23.1 | 64.3 | |
| 23 | 30,960 | 49,700 | 23.0 | 61.4 | |
| 24 | 31,750 | 49,450 | 22.5 | 63.5 | Welded |
| 25 | 30,970 | 49,400 | 21.5 | 58.5 | Welded |
| 26 | 30,450 | 50,300 | 21.0 | 63.2 | |
| 27 | 31,560 | 49,900 | 21.5 | 63.7 | |
| 28 | 30,400 | 49,600 | 22.5 | 64.3 | Welded |
| 29 | 30,320 | 48,600 | 12.5 | 23.3 | Failed in weld |
| 30 | 30,820 | 49,000 | 26.3 | 62.6 | |
| 31 | 30,470 | 49,800 | 23.8 | 57.5 | |
| 32 | 31,400 | 49,400 | 21.6 | 61.5 | Welded |
| 33 | 30,160 | 49,400 | 21.1 | 61.5 | Welded |
| 34 | 31,800 | 49,400 | 20.9 | 61.4 | |
| 35 | 30,450 | 48,900 | 21.5 | 62.9 | |
| 36 | 31,300 | 49,100 | 19.7 | 61.8 | Welded |
| 37 | 31,040 | 49,100 | 20.2 | 65.5 | Welded |

The steel used in the tests was open hearth skelp steel of the following analysis:

| | |
|---|---|
| Carbon | .08% |
| Manganese | .48% |
| Phosphorus | .013% |
| Sulfur | .042% |

The results of the tests are shown on the following page and a photograph of the broken test bars in Fig. 20.

The uniformity of this steel is truly remarkable, even though all the bars were of the same open hearth heat.

Note that the yield point and ultimate strength of the one bar which failed in the weld were not below the average.

### Conclusions

The following points are worthy of comment:

(1) These tests indicate that our cold working in the Flash Weld Department increases the elastic limit of the middle ring steel about 4% and increases the ultimate strength about 8%. There is a decrease in elongation of about 30.7% and a decrease in reduction of area of about 8.7%.

(2) Of the sixteen coupons which included the flash weld, only one failed in the weld itself. This failure was not in the line of weld but through the section where the largest grains are found, immediately next to the line of weld. Even in this coupon, the yield point and ultimate strength were not below the average. This is quite conclusive evidence that our flash welds are stronger than the parent metal.

(3) In coupons Nos. 30 to 37 inclusive, where the flash welds were quenched in cold water as they came from the welding machines, no variations in the physical properties were noted. This was not intended as a heat treatment but we found it desirable to cool the welds quickly due to the difficulty of chipping them while hot. By the time the rings reach the water spray the welds are below the critical temperature, so the quench has little or no effect on the properties. This verified our opinion that we could water cool the welds without running into any difficulty.

# Automatic Gas Cutting—Central Control and Multiple Torch Operation

*By* R. F. HELMKAMP

✦Paper to be presented at Fall Meeting, A. W. S., in Boston, September, 1931, by R. F. Helmkamp of the Applied Engineering Dept., Air Reduction Sales Company.

FROM a position of comparative obscurity a few years ago the fabrication of heavy machine parts has developed steadily on a sensible and sound basis to a point where it has proved its worth both from an engineering and economic standpoint. It is one of the most important of present day industrial processes in the industries of the metal trades. While the acceptance of the idea of fabrication as a practical solution to numerous problems has not been so widespread as its industrial popular appeal, its value to the industries affected is gradually being recognized.

Progress is hindered by lack of definite knowledge of actual applications. Faith in this process has been acquired slowly, and this is as it should have been because the methods employed differ widely from established standard practices and really constitute an independent study.

Knowledge is acquired through patience, vision, well-directed efforts and proved application. The ultimate result is a service to industry and after all, this should be the motive of our efforts. More serious thought to the general application of fabrication to the metal-working industry should result in broadening the present application and reduce the limitations of the process we are considering. Time generally proves that the scope widens as knowledge increases and economic conditions change, but these changes are rarely so radical that individual industries cannot profit by using the process within its limitations.

Industries can be prosperous only when they avail themselves of the resources of advancement and service offered by individuals or companies that devote their energies along the lines of improved methods.

The work that mechanical cutting machines are capable of handling economically is comparatively wide in its scope. Fortunately, it overlaps other processes offering an alternative which should be considered on their respective merits.

Assuming that we are all familiar with the cutting of steel using the oxyacetylene torch as a hand manipulated tool, we will go a step farther and consider this same tool applied to a machine which reduces the human element and makes it possible to control a number of torches at the same time.

There are several phases of multiple plate cutting, but we will consider one class of set-up which com-

prehends a plurality of torches working on individual plates. These to be so arranged that the various controls are centralized at the operator's station. The controls, whether electrical, mechanical or otherwise, to perform satisfactorily the equivalent of manual operation of individual torches, such as turning on and off of preheating gases independently or simultaneously at will, lighting the torches, controlling the

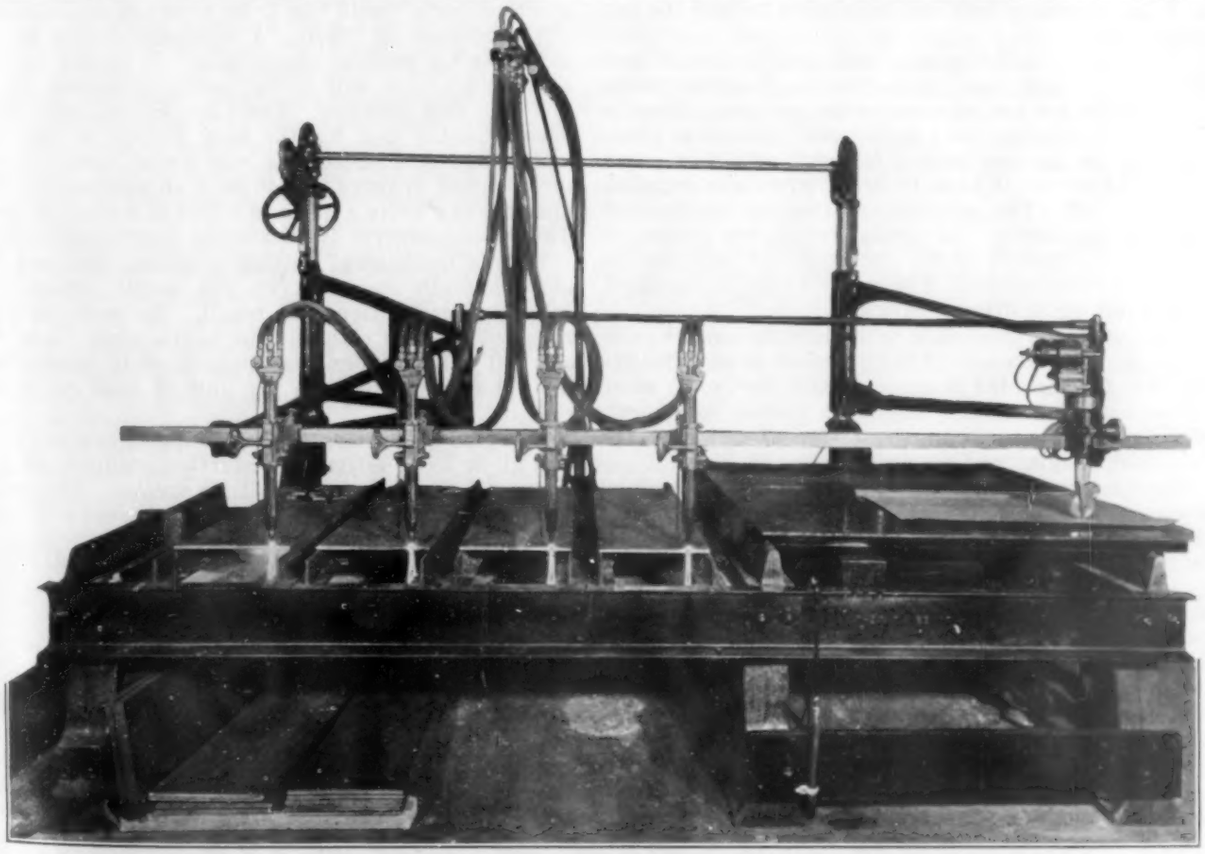
## MACHINE CUTTING TABLE
## OXYGRAPH, CAMOGRAPH AND RADIAGRAPH

### SECTION 1.—MACHINE SET-UP

| Thickness of Steel, Inches | Cutting Tip Size No. | Cutting Tip Style No. | Gas Pressures, Lb. per Sq. In. Oxygen | Gas Pressures, Lb. per Sq. In. Acetylene | Cutting Speed Inches per Minute | Cutting Speed Feet per Hour |
|---|---|---|---|---|---|---|
| ¼ | 0 | 23 | 35 | 4½ | 22—27 | 110—135 |
| ⅜ | 1 | 23 | 40 | 4 | 21—26 | 105—130 |
| ½ | 1 | 23 | 55 | 4½ | 20—24 | 100—120 |
| ¾ | 2 | 24 | 50 | 2 | 18—22 | 90—110 |
| 1 | 2 | 24 | 55 | 2¼ | 14—18 | 70— 90 |
| 1½ | 3 | 24 | 55 | 3 | 12—15 | 60— 75 |
| 2 | 3 | 24 | 60 | 3½ | 9½—12 | 47.5— 60 |
| 3 | 4 | 25 | 50 | 3½ | 8—10 | 40— 50 |
| 4 | 4 | 25 | 60 | 4 | 6.5—8.5 | 32.5—42.5 |
| 5 | 4 | 25 | 65 | 4½ | 5.5— 7 | 27.5— 35 |
| 6 | 5 | 25 | 65 | 4½ | 4.5—5.5 | 22.5—27.5 |

### SECTION 2.—GAS CONSUMPTION

| Thickness of Steel, Inches | Sq. In. per Linear Foot Cut | Total Oxygen—Cubic Feet Per Hour | Total Oxygen—Cubic Feet Per Linear Foot Cut | Total Oxygen—Cubic Feet Per 100 Sq. In. Cut | Acetylene—Cubic Feet Per Hour | Acetylene—Cubic Feet Per Linear Foot Cut | Acetylene—Cubic Feet Per 100 Sq. In. Cut |
|---|---|---|---|---|---|---|---|
| ¼ | 3 | 51 | 0.46— 0.38 | 15.3—12.7 | 11 | 0.100—0.081 | 3.33—2.70 |
| ⅜ | 4.5 | 82 | 0.78— 0.63 | 17.3—14.0 | 13 | 0.124—0.100 | 2.76—2.22 |
| ½ | 6 | 105 | 1.05— 0.87 | 17.5—14.5 | 15 | 0.150—0.125 | 2.50—2.08 |
| ¾ | 9 | 159 | 1.77— 1.44 | 19.7—16.0 | 20 | 0.222—0.182 | 2.47—2.02 |
| 1 | 12 | 174 | 2.49— 1.93 | 20.8—16.1 | 21 | 0.300—0.233 | 2.50—1.94 |
| 1½ | 18 | 240 | 4.00— 3.20 | 22.2—17.8 | 25 | 0.417—0.334 | 2.31—1.86 |
| 2 | 24 | 260 | 5.47— 4.33 | 22.8—18.1 | 27 | 0.568—0.450 | 2.37—1.88 |
| 3 | 36 | 332 | 8.30— 6.64 | 23.0—18.5 | 32 | 0.800—0.640 | 2.22—1.78 |
| 4 | 48 | 384 | 11.82— 9.03 | 24.6—18.8 | 35 | 1.078—0.824 | 2.24—1.72 |
| 5 | 60 | 411 | 14.94—11.76 | 24.9—19.6 | 37 | 1.346—1.058 | 2.24—1.76 |
| 6 | 72 | 479 | 21.30—17.43 | 29.6—24.2 | 36 | 1.600—1.310 | 2.22—1.82 |



**Oxygraph with Four Machine Cutting Torches and Station Control**

cutting oxygen jet and starting and stopping the tracing device that follows the template or drawing of desired contour, must make the several torches traverse the same contour, thereby producing like pieces in multiple.

In order to understand better the several factors involved in such an arrangement, we will consider them in the order of general set-up and procedure.

The first consideration is a mechanical cutting machine of suitable design and construction that may be fitted with additional torches. These should be attached to the machine in such a way that they can be readily removed, be changed as to distance apart, provide adjustment for bevel cutting and be capable of being operated in unison, or as individual torches, shut off selectively as the size and class of work demands.

An arrangement of this kind suggests a central control. The logical place for this control is at the operator's station. From this point the operator may turn on the acetylene or fuel gas, light the torches simultaneously, turn on the preheating oxygen and have the preheating flames burning ready to start on the cutting operations; then start the motor, and control the oxygen cutting pressure as desired.

These controls may be actuated by electrical, mechanical or other arrangements. We are prepared to demonstrate an electrically-operated unit that is arranged to handle four torches simultaneously, controlled from a central point.

The additional apparatus and equipment needed to install such a machine is the proper number of three-hose machine torches, special electrically-operated control valves, gas-equalizing and distributing manifolds, pilot control, manifold pilots for torch ignition and the necessary hose and regulators to feed the gas supply lines.

The control unit has been built into a compact and convenient form, and is preferably mounted fairly close to the torches in a suspended position, allowing it to float with the torch movement. The close proximity to the torches results in quick action of gases and a minimum of hose to drain when gas supplies are shut off. The electric switches or mechanical controls that control the special valves, are located at a point convenient to the operator and adjacent to the pilot light control. The motor switch is mounted on the tracing or driving device.

The cutting of steel plate with multiple torches calls for a jigging arrangement for the work pieces. Realizing that the machine is accurate and that when steel is cut with the oxyacetylene torch certain movement of the work piece results, the design of a jigging arrangement begins to take on importance.

The first requisite is that the jig and the template supports be level with each other. The jig should be so arranged that the multiple torches do not operate on one plate but rather single torches each operate on a single plate fed into the cutting area, that part of the plate in the cutting area being free to move due to the heating effect of cutting, yet supported so that the scrap and the shape cut will not fall as the cutting is completed for a given contour. The other part of the plate should be held by the jig so that the movement mentioned will not affect the uncut portion.

After a contour has been traversed by the tracing or driving device, and the several torches each cut the same shape from the several plates, the plates may be moved ahead in the jig to a stop that spots them for successive cuts. This brings us to the realization that the set-up of the jig and the template should be carefully and securely done so that material may be used with a minimum of scrap resulting, and produce accurate work. Anchoring the jig and template securely keeps them in their relative position, and is necessary since the movement of plates on and off would tend to disturb such a set-up if this important detail were neglected.

Making the set-up for a production job involving multiple-torch operation, is a real mechanic's job, and the more exacting the set-up man is, the better the results will be. Often, however, the tolerances are fairly lenient and time is saved.

It should be remembered that the cutting of steel by this process is comparable to a roughing machine cut, and the engineers and designers who fully appreciate this can lay their plans within the limitations. Since most work cut out is either for fabrication by the welding process or to be machined further for its ultimate purpose, the needed tolerances for various thicknesses do not seem unreasonable.

As material increases in thickness we ask for greater tolerance. This is to insure a usable piece of cut material. Ofttimes due to defects in the steel, or factors unseen and beyond control a slightly undesirable surface will result. In cases where the work is to be machined the tolerance needed is enougn to machine out such irregularities. In cases where the work goes into a welded product, this can be taken care of at the time of welding. Then, again, in cases where the defect is of such a character that it makes the piece unusable it is a blessing in disguise for the torch will show up metallurgical defects such as sulphur segregations that alternative machining methods often fail to do. We feel positive that the fabricator of machine parts would like to be aware of such defects.

The method of tracing a template should be the most flexible process conceivable. It should be possible to trace at will square corners, reverse curves and long slim contours. There are several methods of accomplishing this, but the most flexible is that type which may be adopted to a substantial template or a dimensioned drawing. With such an arrangement the operator can write a name in script in a piece of steel. This would suggest its flexibility beyond question.

With a mechanical cutting machine, equipped for multiple-torch operation we can safely expect that increased production will result. No more labor is required and the elapsed time is the same. And the gas bill per unit remains approximately constant as the cubic feet of oxygen per unit of steel cut is unchanged.

Accepted production figures in linear feet per hour will allow us to estimate production with any sort of set-up, whether single or multiple torches. The possibilities of increased production are apparent with multiple torches, together with the convenience of meeting production schedules and when you consider the flexibility of the equipment, in that it will produce any sort of contour desired, it takes on a real value.

To sum up this process, we have the advantage of increased production in the same elapsed time, no increase in labor cost and floor space required. This aids materially in meeting rush production schedules.

With a demonstration of the difference between the old method of single torch operation involving direct manual control and the central control and multiple torch operation which puts all controls at the command of the operator, you can be the judge of the advantages of multiple torch machine cutting.

# Large Welded Everdur Pressure Vessels

By MARSELIS POWELL AND I. T. HOOK

✦Paper to be presented at the Fall Meeting, A. W. S., in Boston, September, 1931, by Marselis Powell, General Foreman, The Whitlock Coil Pipe Company and I. T. Hook, Research Engineer, The American Brass Company.

THIS comparatively new engineering material is an alloy of copper, silicon and manganese in the approximate proportions of 96, 3 and 1. Developed originally as a corrosion resisting, non-sparking, high strength alloy for use in the manufacture of explosives, it has attained wide popularity as a material for large and small hot water storage vessels, chemical apparatus and similar purposes. Pressure vessels in all sizes from 5½-in. diameter resistance seam welded kerosene containers to 10,000-gal. hot-water storage accumulators have been made.

Some of the largest of these have been of riveted construction, but for the moment we are interested only in the welded vessels, and, again for the moment, we are interested only in the larger sizes, leaving out of consideration range boiler sizes and smaller.

## Reasons for Welding

Copper alloys, higher in first cost than steel, must find their economic justification by reason of the quality of service rendered and their low depreciation cost. In designing pressure vessels to be made of a corrodible metal it is necessary to make an allowance in the safety factor for strength *after* a portion of the metal has been eaten away. Hence additional thickness is provided when the corrodible vessel is new to take care of the strength when it is old. In the case of Everdur subjected to hot water, the attack has so little effect on the metal that no additional thickness is necessary.

The designer, therefore, having cut the safety factor to the lowest value consistent with satisfactory service desires the highest possible efficiency of seams. To do this with rivets means a very complicated layout, with a considerable increase in cost of material for butt straps, rivets and labor. In ½-in. thick plates, for instance, it is necessary to use a double butt strap, quadruple riveted connection in order to secure better than 88 per cent efficiency. Numerous tests on welded Everdur seams have proved that such can be consistently made with an efficiency equivalent to or better than a triple riveted double butt strap connection. Welding, therefore, appears to be the desirable method of connection provided the metal is readily weldable and provided further that the welding heat causes no serious structural or chemical change in the base metal as is the case with some of the ferrous alloys.

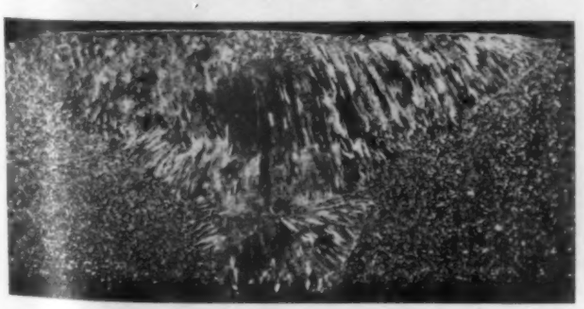
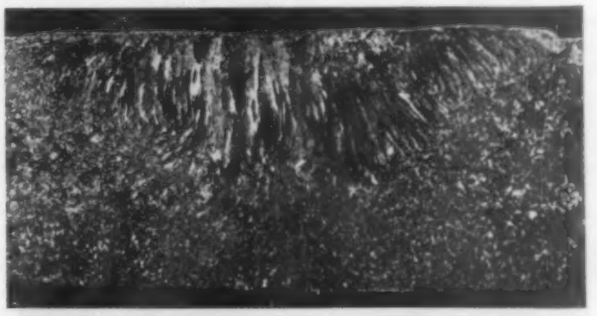


Fig. 1
Transverse section of seam with metal in as-welded condition. Note the coarsely dendritic or cast structure of the weld metal

Fig. 2
Section of weld seam after annealing at 750° C. The locked-up stress would be entirely eliminated by the anneal but the anneal was not high enough nor long enough to change materially the structure of the weld metal



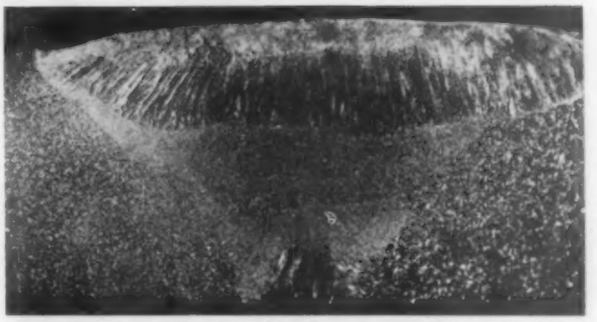


Fig. 3
Section of welded seam each bead of which has been severely peened with an air hammer. The original locked-up stress is largely dissipated by the peening and replaced by less concentrated stress due to the cold work. The lower beads have had their structure refined by the peening followed by the welding heat from the bead above

## Everdur and Copper

In order to understand the general properties of the new metal, a comparison in tank sheet thickness is made to those of copper, which metal is generally known.

| Property | Value for Copper | Value for Everdur |
|---|---|---|
| Color | Copper red. | Distinctive bronze. |
| Density | 8.90 | 8.46 |
| Tensile strength, lb. per sq. in.: | | |
| Annealed condition | 32,000 | 52,000 |
| Cold rolled condition | 45,000 | 75,000 |
| Elongation in 2 in., per cent: | | |
| Annealed condition | 35.0 | 50.0 |
| Cold rolled condition | 15.0 | 35.0 |
| Corrosion resistance | Good. | In general better than copper. |
| Heat conductivity, Cal/cm3/sec/ Deg. C. | 0.91 to 0.94 | 0.078 |
| Electrical conductivity, per cent of I.A.C.S., 20 deg. C. | 97 to 101 | 6.5 |
| Melting point, deg. F. | 1,981 | 1,866 |
| Melting point, deg. C. | 1,083 | 1,019 |
| Machinability | Difficult, drags with tool. | Excellent. |
| Weldability | Good in thicknesses of ¼ in. or less. Difficult in tank sheet thicknesses, ⅜ in. or above. | Excellent by any method. |

The difficulty in welding thick sheets of copper is explained almost wholly by its high heat conductivity. In order to raise the temperature of the seam edges to the melting point, it is necessary to pour the heat into it at such a high rate as to tax the capacity of

Fig. 4
Section of welded seam with each of four beads severely peened with an air hammer and annealed in a muffle at 550° C. The macrograph shows almost complete refinement of the structure of the weld metal

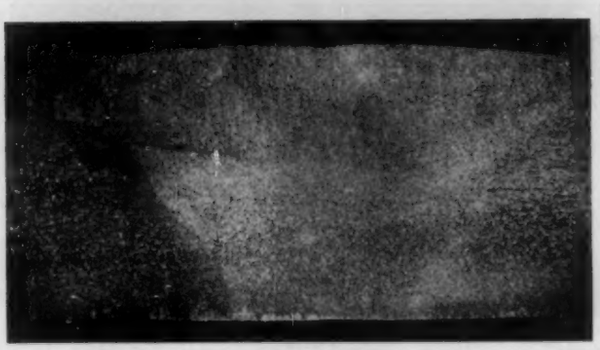


Fig. 5
Same as Fig. 4, except annealed at 650° C. More complete refinement of grain than that obtained in the case of Fig. 4

the usual welding apparatus and to make it uncomfortable for the operator as well. Everdur, having a very low heat conductivity, can be readily welded without resorting to preheat.

## Welding Procedure

In working out a welding procedure, the first objective is sound weld metal with perfect penetration or bond to the base metal. Secondly, the nature of the weld metal and means of improving same by such auxiliary operations as peening and annealing must be considered.

A definite setting of welding apparatus for any given job can best be determined by a short preliminary trial under the exact conditions to be used in the set-up. However, general principles can be laid down:

(1) Everdur should be *welded as rapidly as possible.** The reason for this is that it is desirable to keep the shrinkage stresses in the red hot metal as low as possible, and, of course, the best way to avoid them is to cut the heat flow into the base metal as short as is consistent with good union. This rule holds whether the welding be done with the oxy-acetylene torch or the electric arc. Moreover, the most homogeneous solution the metal can have is that of its liquid state. Hence the quicker the metal is solidified, the more uniform will be the cold metal and the finer its structure.

*As an illustration, a welder familiar with the welding of steel was given a 12-in. seam in ½-in. Everdur plates to weld using the oxy-acetylene torch. He executed the weld in 26 minutes. He was then told to weld a similar pair of plates just as fast as he could fuse the metal, and he did this one in 8 minutes. Tests on the first weld over which he had taken so much time showed an efficiency of only 51 per cent, average of three tests, while those on the one where the welding had been speeded up showed an average of 73 per cent. The latter would have been 84 per cent or better except for a cold shut in one test sample—he had evidently moved a bit too fast.

(2) Where *maximum strength and ductility in the weld* is desired steps must be taken to eliminate locked-up stress and to restore the structure to one similar to that of the rolled sheet. As will be brought out in the following discussion, some form of cold work, such as rolling or peening followed by an anneal, will be found desirable. This applies more particularly to welds in thick sheets. For thin sheets 3/16 in. and under, the cooling from the welding temperature is so extremely rapid as to give excellent strength and ductility in the weld metal. Moreover, the reenforcement is usually a higher per cent of the original thickness in thin sheets than is the case with thick sheets.

## Plan of Investigation

In order to investigate all possible variations a carefully made series of tests were run on ½-in. plate. A microscopic study was necessary to bring out structural changes. For the most part, it was found that a five diameter macrograph gave a better picture of the weld structure than a higher magnification. All of the conditions are illustrated below in Figs. 1-7.

## Results of Investigation

The following detailed results show values which were obtained on the test samples made under the conditions illustrated above. The strengths shown are not the maximum obtainable. A skilled operator can undoubtedly improve on them—but they are representative of good work. Most of the preliminary work was done with the metallic arc as the total heat employed in depositing a given weight of metal can be made more constant therewith than it can when the torch is used.

Fig. 6
Same as Fig. 4, except annealed at 750° C. The annealing temperature is evidently too high as the structure of both the weld metal and the base metal has begun to coarsen

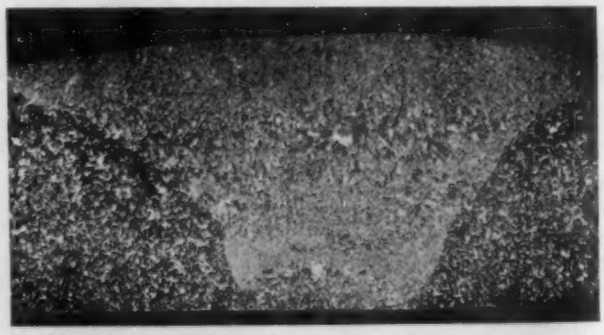


Fig. 7
Section of seam welded and peened the same as those illustrated above but instead of annealing in a muffle which takes 30 to 40 min., the hammered seam was annealed by oxy-acetylene torch requiring only about one minute and 40 seconds black to black. Max. temperature as read from thermocouple welded to underside plate at 660° C., with torch playing on top side. Sturcture completely refined

Except where otherwise stated all of the welds were made in four beads with 5/32 in. diameter Everdur electrode with 190 amperes and an arc voltage of approximately 28, 90 deg. single "V" groove. All of the reenforcement was machined from the tensile and bend test samples. The 2-in. gage length was very nearly prismatic in section. The illustrations show the section of the weld before the reenforcement was machined off. Averages of two to four tests and average of work of two welders.

| Illustration | Photo No. | Size Tested Inch | | Yield Point* | Tensile Strength | Elongation in 2 In., % | Free Bend Elong. in ½ In., % | Test No. |
|---|---|---|---|---|---|---|---|---|
| | | Thickness | Width | Lb. per Sq. In. | | | | |
| Tested in as-welded condition: | | | | | | | | |
| Fig. 1 | 7,158 | 0.484 | 1.497 | 22,000 | 34,300 | 10.2 | 28.0 | 25,693 |
| Welded and annealed at 750 deg. C.: | | | | | | | | |
| Fig. 2 | 7,159 | 0.494 | 1.502 | 16,100 | 30,500 | 12.0 | 40.0 | 25,694 |
| Welded in four beads, each air hammered (not annealed): | | | | | | | | |
| Fig. 3 | 7,160 | 0.496 | 1.502 | 29,600 | 44,700 | 10.3 | 24.0 | 25,695 |
| Ditto except annealed in muffle at 550 deg. C.: | | | | | | | | |
| Fig. 4 | 7,185 | 0.514 | 1.515 | 34,700 | 45,900 | 8.8 | 43.0 | 26,351 |
| Ditto except annealed in muffle at 650 deg. C.: | | | | | | | | |
| Fig. 5 | 7,181 | 0.518 | 1.498 | 24,200 | 46,800 | 15.5 | 47.0 | 26,352 |
| Ditto except annealed in muffle at 750 deg. C.: | | | | | | | | |
| Fig. 6 | 7,182 | 0.505 | 1.534 | 17,300 | 38,400 | 16.8 | 42.0 | 26,353 |
| Ditto except annealed at approximately 660 deg. C. with oxy-acetylene torch: | | | | | | | | |
| Fig. 7 | 7,183 | 0.528 | 1.512 | 21,600 | 44,500 | 19.5 | 71.0 | 26,354 |
| Boiler shop weld in three beads double 90-deg. V-groove (one side twice as deep as the other) air hammered and torch annealed: | | | | | | | | |
| Fig. 8 | 7,063 | 0.509 | 2.002 | 25,400 | 44,000 | 13.5 | ... | 23,115 |
| Fig. 8 | 7,063 | 0.510 | 2.019 | 33,600† | 62,000† | 25.0† | ... | 23,115 |

*Yield point at ¾ per cent extension under load.
†Reinforcement of 0.35 in. not machined off.

### Conclusions from Preliminary Investigation

A study of the above investigation brings out the following points:

(1) Locked-up stresses in Everdur welds in ½-in. plates are of little moment. Tested in the as-welded and the welded and annealed conditions, there is no gain by the annealing. In fact, the annealed sample showed a lower strength than the welded sample containing all locked-up stress from the welding strains. This was due in this case to too high an anneal, the 750 deg. C. being sufficient to start recrystallization of the rolled metal.

(2) Annealing of the weld confers no benefit on the connection unless the weld metal first be cold worked. Referring to Fig. 1 we see that the weld metal is coarsely dendritic growing perpendicular to the surface on which the molten metal was deposited. Fig. 2 shows that in the 40 minutes the sample was kept in the furnace (held 5 minutes at 750 deg. C.) the dendritic structure of the weld had changed but little, though the temperature was high enough to coarsen the structure of the base metal.

(3) In the case of the hammered but not annealed specimen, Fig. 3, the hammering of the first beads followed by the welding heat of the later beads gave a refinement to the structure of all but the last bead which remains dendritic though partly broken up just under the hammered surface. The cold work exerts a marked benefit to the weld reflected in the yield point and the tensile strength.

(4) Cold work on the weld metal followed by an anneal of approximately 650 deg. C. improves welded connections in Everdur in both tensile strength and ductility.

### Discussion

Just how much cold work to give the weld metal is illustrated in Fig. 8. Here the sample was laid in a

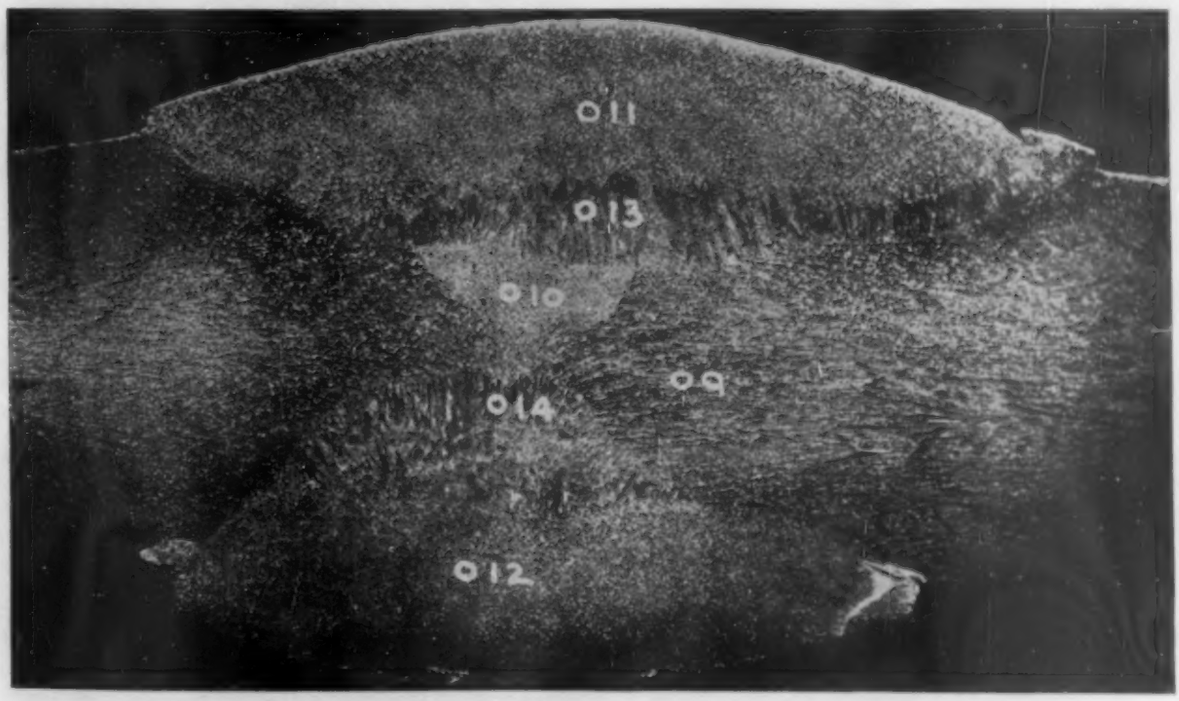



**Fig. 8**

Section of boiler shop weld. Each of the three beads was severely peened with an air hammer and the seam then annealed with an oxy-acetylene torch to a dull red heat estimated at 650° C. (1200° F.). Incomplete refinement of structure due to the fact that the peening effect extends only .22 inch to .26 inch below the hammered surface. The numbered circles show the location of micrographs, Figs. 9 to 14 inclusive

favorable position and peened three times by an experienced boiler maker using a heavy air hammer. It was then torch annealed to a dull red about 650 deg. C. or 1200 deg. F. The metal showed color for approximately 35 seconds in the annealing operation. The torch was applied on only one side, but the color was observable on the opposite side of the sheet. An inspection of the sample showed that the weld metal was recrystallized to a depth of from .22 in. to 26 in. under the hammered surface.

It can be stated, therefore, that the weld metal should be placed in beads approximately ¼ in. thick, wire brushed and thoroughly peened.

Fig. 9 to 14 inclusive show micro-photographs of the structures of the metal at various points. All of them are taken with a magnification of 75 diameters. Fig. 9 shows a characteristic Everdur forged structure. The metal is a solid solution in the alpha phase with polyhedral grains, many of them showing twin bands. The base metal at this point (about .2 in. back from the apex of the weld) had been entirely unaffected by the welding or annealing heat.

Fig. 10 shows the structure at mid-depth of the first bead. It has been refined by the air hammering followed by the heat of the third bead and by the torch anneal. It is identical with that of the base metal except that the grains are larger. The same is true of Figs. 11 and 12 taken in beads 3 and 2 respectively.

Figs. 13 and 14 are taken near the bottom of beads 3 and 2 respectively. They were so far below the hammered surface that the metal had received too little cold work. It did not, therefore, recrystallize in the quick anneal given it and the microscopic study shows the typical dendritic structure brought out more clearly in Fig. 8.

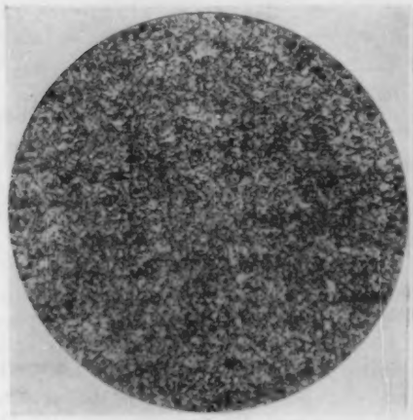


**Fig. 9**
Structure of original rolled Everdur used in the weld of Fig. 8. Typical polyhedral grains, many of them twinned

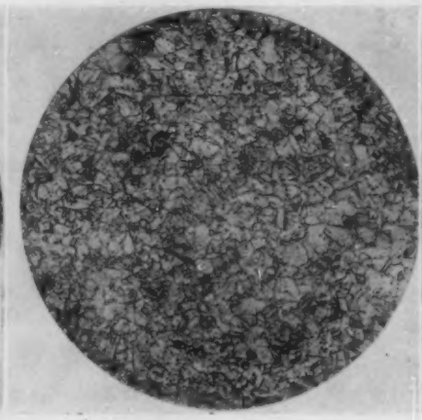


**Fig. 10**
Structure of weld metal in mid-point of first bead. The peening and annealing has caused the weld metal to recrystallize similar to the original metal except that the grains are larger

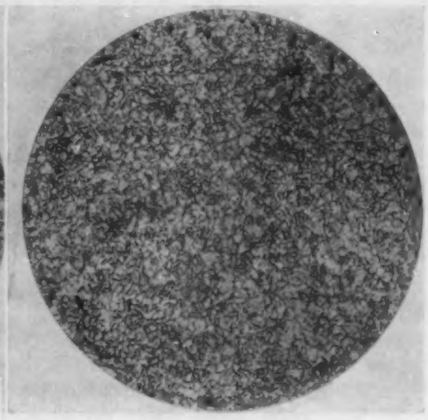


**Fig. 11**
Structure at mid-depth of third bead. Shows recrystallization similar to original metal

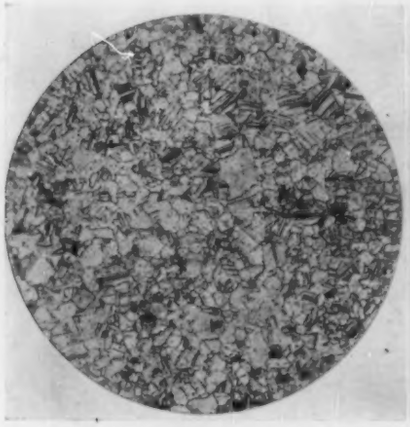


**Fig. 12**
Structure at mid-depth of second bead. Shows recrystallization similar to original metal except that grains are larger

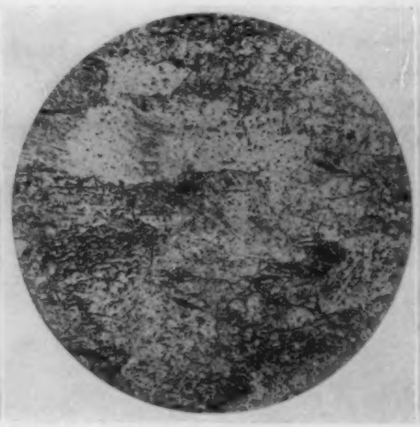


**Fig. 13**
Structure .28 in. below hammered surface of third bead. Peening has not reached deep enough to cause recrystallization. Still dendritic

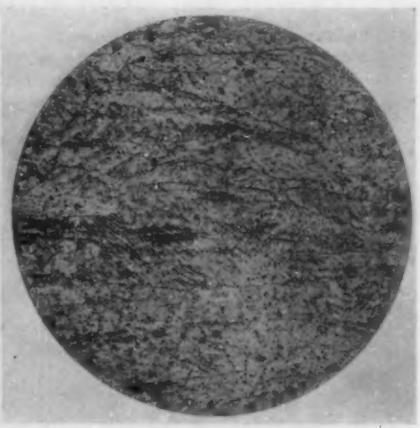


**Fig. 14**
Structure .35 in. below hammered surface of second bead. Peening has not reached deep enough to cause grain refinement. Still dendritic

A weld can be very quickly annealed with the oxy-acetylene torch. A comparison of the welds annealed in a furnace muffle where from 30 to 40 minutes were required to bring the ½-in. plate up to the proper temperature showed inferior results to those where the weld was heated locally by a torch blast to a dull red for only 30 to 40 seconds. The reason for this is that the severely cold worked weld metal recrystallizes readily at this temperature (approximately 650 deg. C. or 1202 deg. Fahr., a dull red just showing color on the side lighted by the torch but more plainly visible on the dark side opposite the torch) while the state of solution or crystallization of the hot rolled base metal is affected not at all.

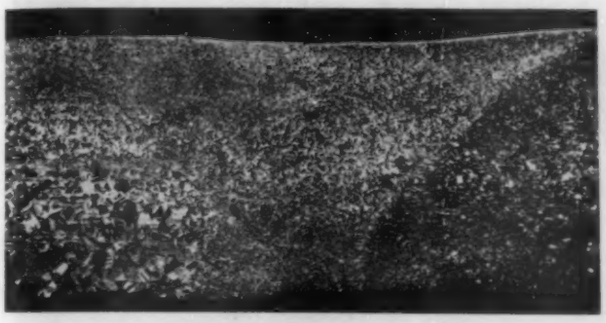


**Fig. 15**

Test No. 26,572—Oxy-acetylene weld on ½ in. thick Everdur plate. The structure of the weld itself has been refined by the peening and annealing treatment. The base metal adjacent to the weld has been coarsened in structure by the welding heat. It was not refined by the torch anneal as it received little of the cold work of the hammering operation

### Final Series—Various Thicknesses

Having established a procedure from the foregoing data a series of welds was made on Everdur tank sheets in thicknesses from ¼ in. to ¾ in. In all of the metallic arc welds, a 5/32-in. diameter metal arc electrode with 190 amperes and approximately 28 arc voltage was used. Each bead was peened thoroughly with an air hammer. In the case of the oxy-acetylene welds, the single V-groove was filled in one pass and the welds peened on top and bottom only.

All of the welds on completion were annealed with the oxy-acetylene torch at approximately 650 deg. C. (1202 deg. Fahr.). The temperature was estimated by the dull red color, but it was actually checked by means of an iron-constantan thermocouple welded to the bottom of the plates. The thermocouple readings vary from 620 deg. C. to 700 deg. C. It was noted that there was a tendency on the part of the torch operator to anneal at too high a temperature. One caution in the handling of the torch may be necesary in cases where the seam runs out to an edge, the annealing should always start from an inside point and finish at the edge. If started at the edge a crack may result due to tension at the edge when the torch is moved inwards.

The results of these tests are fairly representative of values that can be obtained by a careful operator. They do not represent the maximum obtainable. This is more paticularly true of the oxy-acetylene welds than of the metallic arc welds. The procedure for the latter has been worked out in greater detail and the total heat can be more readily duplicated than with the torch. Also since the peening can be depended upon to break up the cast crystallization to a depth of only ¼ in. below the hammered surface, it follows

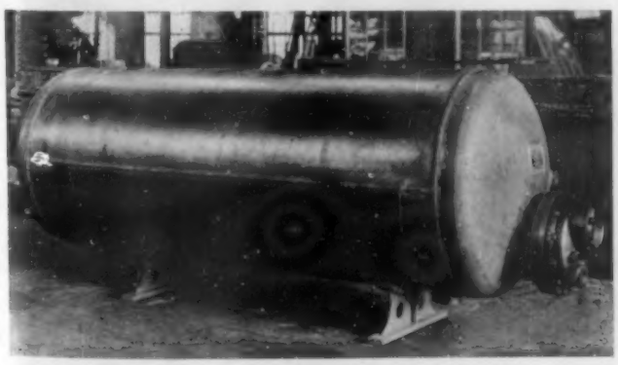


**Fig. 16—500 Gallon All-Welded Everdur Pressure Vessel**

that with the weld completed in one pass, ½-in. plate is the maximum thickness that can be properly worked. It should be understood further that the reenforcement was machined off in all of the following tests. Results thus, averages of two or more tests:

| Plate Thickness, In. | Size Tested, In. Thick | Size Tested, In. Wide | Yield Point* Lb. per Sq. In. | Tensile Strength Lb. per Sq. In. | Elongation in 2 In., % | Free Bend Elong. in ½% | Test Number |
|---|---|---|---|---|---|---|---|
| Metallic arc welds, all 5/32-in. diameter Everdur wire, 190 amperes, 28 volt arc, each bead peened, torch annealed at 650 deg. C., one bead. | | | | | | | |
| ¼ | 0.245 | 1.496 | 21,200 | 49,450 | 27.7 | 50 | 26,558 |
| Ditto except two beads. | | | | | | | |
| ⅜ | 0.369 | 1.499 | 23,700 | 50,150 | 24.7 | 55 | 26,560 |
| Ditto except four beads. | | | | | | | |
| ½ | 0.520 | 1.260 | 21,600 | 46,230 | 21.5 | 52 | 26,562 |
| Ditto except five beads with current value of 225 amperes on first two beads only. | | | | | | | |
| ¾ | 0.770 | 1.265 | 20,500 | 40,700 | 18.5 | 63 | 26,564 |
| Oxy-acetylene welds, ⅛-in. diameter Everdur welding rod, one pass, Everdur flux,† peened top and bottom, torch annealed at 650 deg. C. | | | | | | | |
| ¼ | 0.238 | 1.500 | 22,100 | 49,500 | 26.0 | 44 | 26,568 |
| ⅜ | 0.366 | 1.482 | 23,300 | 46,150 | 23.5 | 61 | 26,570 |
| ½ | 0.508 | 1.258 | 21,500 | 46,300 | 28.7 | 78 | 26,572 |

Fig. 15

*Yield point at ⅜ per cent extension under load.
†Made up of 90 per cent fused borax plus 10 per cent sodium fluoride used dry or mixed with absolute methyl alcohol.

### Discussion of Results—Sheets of Various Thicknesses

The elongation in the free bend test is obtained from the increase in length of the top surface of the weld metal in a gage length of ½ in. The elongation

**Fig. 17—10,000 Gallon Everdur Hot Water Accumulators, All-Welded**

in 2 in. obtained in the tensile test, included all of the stretch in the weld as well as that of the base metal in the gage length. In general, the elongations indicate a reasonably good ductility. As measured in this manner, the toughness of the weld metal is doubled by the peening and annealing treatment.

The tensile strength of the weld metal in the ¼-in. and ⅜-in and ½-in. thick sheets is about as high as can be expected in good work. A reenforcement of the order of 1/32-in., 1/16-in. and 3/32-in. for the ¼-in., ⅜-in. and ½in. sheets in the order named is all that is required to develop the full strength of the base metal.

For thicker sheets, as for instance ¾-in. and 1-in., the procedure has not been worked out to the same refinement of detail as is the case with sheets of ½ in. or less. Using the metallic arc, welds in thick sheets offer no particular difficulty. It is probable, however, that a double V-groove would yield better results than the 40,700 lb. per square inch obtained with the single Vee used in the ¾-in. sheet of the above series. The contraction strains arising from the considerable heat flow in thick base metal, ¾ in. thick and above, during a gas weld causes difficulty from hot short fractures in the weld metal. A proper procedure to eliminate such imperfections in gas welds has not been worked out at this writing.

The yield point is rather quickly raised by suitable cold work such as hammering the weld or more easily,

by a simple over-stressing. If, for instance, the metal is stressed to 30,000 lb. per square inch, it will take a slight permanent set and the yield point will be raised to a value somewhat less than this while the tensile strength will be entirely unaffected.

### Everdur Pressure Vessels—All Welded

In the following paragraphs, the actual manufacture of three large Everdur pressure vessels is discussed. The first of these, Fig. 16, is of 500-gal. capacity designed for working pressure of 100 lb. per square inch, while the other two, Fig. 17, each have a capacity of 10,000 gal. and are also intended for a working pressure of 100 lb. per square inch. The vessels were fabricated entirely by metallic arc welding.

### 500-Gal. Storage Heater-Construction Details

This vessel is 42 in. diameter by 144 in. long with dished and flanged heads. The shell was rolled up

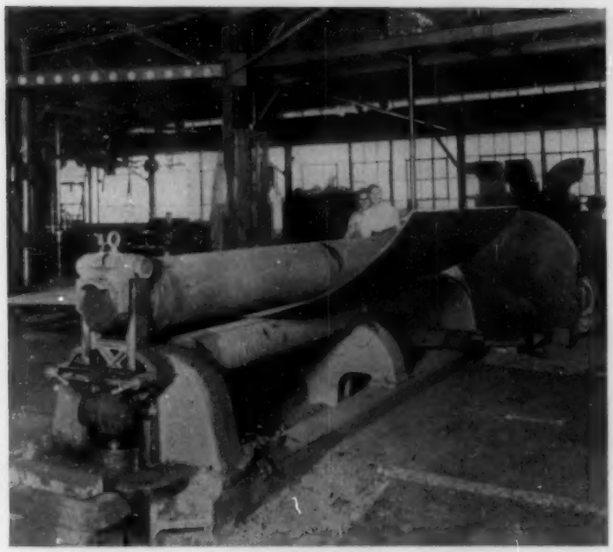


Fig. 18—½ In. Everdur Plate in the Bending Rolls

using ¼-in. Everdur plate while the heads were hot-spun from ⅜-in. thick plate.

The longitudinal seam and girth seams were made with a single V joint scarfed for a 90 per cent opening. The longitudinal seam was tacked approximately every foot and welded by the back step method to prevent any buckling or warping in the seam. The seam was welded in a single pass, using 190 amperes with a 5/32 Everdur electrode. A reinforcing bead was run on the inside using the same current and electrode. The seam was then hammered severely from both sides with an air hammer using a knurled tool.

The large holes in the heads, one for the manhole ring, the other for the head port nozzle, were cut on a boring mill. The head port nozzle was made from a ¼-in. plate rolled to 15 in. O.D. and the seam welded using 190 amperes 5/32 electrode. This seam was hammered and annealed to about 1200 deg. Fahr. A flange was turned up on this short cylinder and a steel reinforcing ring clamped behind it and welded securely to the nozzle. The steel ring formed a very rigid support for the bolts which held the tube sheet and head against the nozzle. This nozzle was welded into one head using 190 amperes 5/32 electrode making a heavy fillet weld in one pass both inside and outside.

Into the other head, a heavy Everdur manhole ring

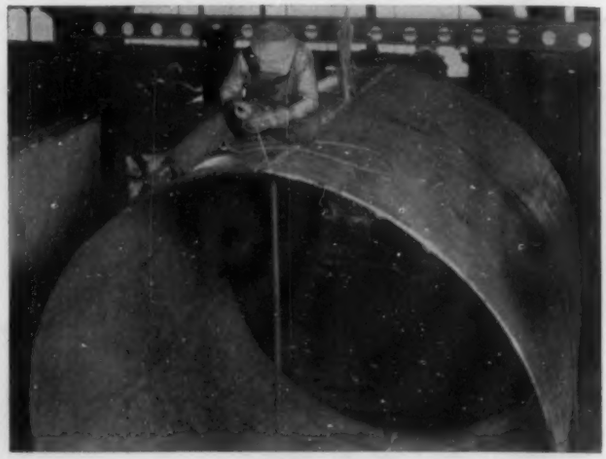


Fig. 19—Welding Longitudinal Seam

was welded using 270 amperes with a ¼-in. electrode, making a single fillet weld both inside and outside. These welds were both hammered severely with an air hammer using a knurled tool. The heads were welded to the shell by the same method as employed in longitudinal seam.

The openings for the various pipe connections were made by melting out the Everdur with an acetylene torch to very nearly the proper size and then accurately finishing these holes with an air chisel. The fittings were welded in by means of a series of single beads run round them to form a rather heavy fillet weld. These welds were all hammered with an air hammer using a knurled tool.

After the welds were completed, they were all annealed to a temperature of about 1200 deg. Fahr. with a gas torch excepting, however, the weld which joined the steel backing ring to the Everdur nozzle, which was not annealed.

Fig. 20—Assembly of Weld and Shell

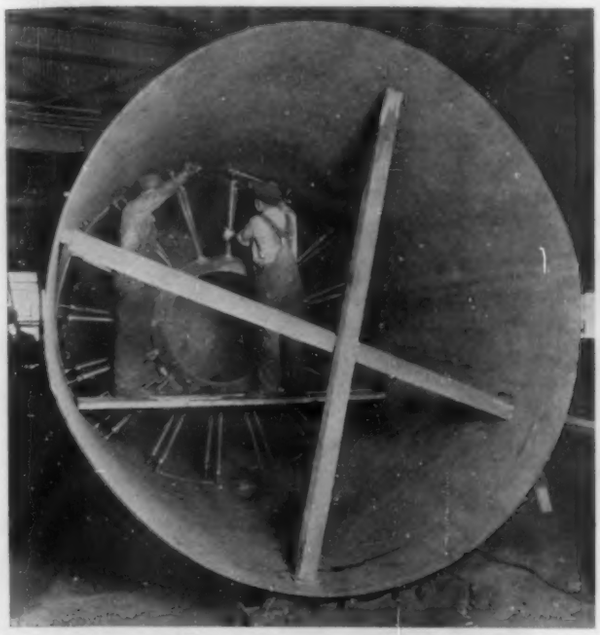


Fig. 21—Assembly of Two Courses (Inside View)

### 500-Gal. Storage Heater-Pressure Test

The shell was tested to 300 lb. per square inch or three times the designed working pressure. This pressure developed a stress in the shell wall of 25,200 lb. per square inch which was slightly in excess of the yield point of the Everdur metal. Consequently, a circumferential expansion was noted which showed upon the release of the pressure a permanent increase in circumference of approximately ⅛ in. Subsequent applications of the 300-lb pressure, however, left no further permanent increase in the circumference. This observation shows that the comparatively low yield point in hot rolled Everdur is rapidly raised by overstressing the metal. The severe stress of the test pressure was held by the welds with no indication of distress.

### 10,000-Gal. Accumulators—Construction Details

These two large accumulators shown in Fig. 17 are 108 in. in diameter x 264 in. long. The shell is made from ½-in. Everdur plate in two courses, each course contains two sheets. Dished and flanged heads, one .75 in. thick with a manhole and the other a plain head .65 in. thick were used. In all there were 125 lineal feet of welded seams in each vessel exclusive of welded nozzles and fittings.

Fig. 22—Assembly of Two Courses (Outside View)

The fabrication of the Everdur in all the operations —shearing, scarfing and rolling—Fig. 18—were the same as if the metal had been ordinary low carbon steel plate.

The longitudinal seams—Fig. 19—were of the double V type and welded in three passes. The plates were scarfed so that the opening on the outside was twice that of the one on the inside. The first pass filled the outside V about one-half full. The seam was immediately turned over and the inside V filled with the second pass. These two beads were then hammered, using two air hammers working directly opposite each other. The outside bead was hammered with a flat smooth tool. On the inside bead the tool used was round and slightly convex, also smooth. The third layer was then applied on top of the first and hammered, using the same tool used on the inside. A copper angle was used to back the seam for the first layer. All the welds were made with 190 amperes on a 5/32 diameter Everdur electrode and a sprinkling of flux on the seam.

In setting up the girth seams for welding, a cart-wheel jack was used to hold the course in a true circle. Fig. 20 shows head being tacked to one course. This joint was a single V weld made in four passes, three on the outside in the V and one on the inside, each pass slightly less than ¼ in. in thickness. Each layer

Fig. 23—Hammering the Welded Seams

of the weld was hammered before the successive layer was applied. The tools used in hammering this weld were the same as in the longitudinal weld. Layers 1 and 2 were hammered with a flat smooth tool and layer 3 with a round convex tool. The fourth layer on the inside was hammered with a concave tool, which straddled the weld and brought it down all at once. The hammering operation is illustrated in Fig. 23.

The center girth seam—Fig. 21 inside and Fig. 22 outside—was a duplication of the head girth seam.

The openings in the heads and shells for the pipe connections were cut out by drilling and finishing with an air chisel. The connections were welded both inside and outside by means of single beads run round them, each layer of these beads being hammered with a smooth flat tool.

The annealing of all the welds was done with gas torches. The weld and metal adjacent to it was brought to a temperature of about 1200 deg. Fahr.—Fig. 24. This temperature was estimated by the color, a cherry red, noted on the side of the seam opposite the torch. The seams were allowed to cool naturally and

Fig. 24—Annealing the Hammered Seams

each portion of the weld retained color for about 40 seconds.

### Remarks on Cold Working—Arc Characteristics, Etc.

The only variable in the welding procedure used on Everdur which is difficult to control is the hammering. Several conditions are present—the shape of the tools used, the weight of the blow struck and the number of blows struck over a given point. The hammering on the welds of the large accumulators was enough to reduce the thickness of the weld approximately 1/16 in. for each hammered surface. The time consumed in hammering was a little more than was required to actually deposit the metal.

The arc made between Everdur rod and Everdur plate is most effective with the electrode positive. There is no apparent crater and to a welder used to welding steel, it would seem that no penetration was taking place. Because of this characteristic, it is necessary to prepare the joint to be welded with a little greater opening than for steel welding. The molten metal in the Everdur arc is also much more fluid than in the steel arc, so that with the greater opening it is imperative that the seam or joint be backed with a bar or plate, preferably copper. The fluid condition of the metal in the arc also makes it necessary to weld in a flat position.

The time required for actual depositing the metal is much less for Everdur than steel. However, the refinement of the weld metal takes time enough so that the actual cost of an Everdur weld in labor is somewhat more than a similar weld in steel.

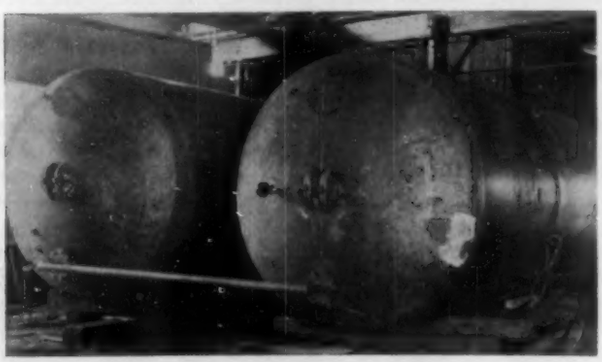


Fig. 25—Vessels on Test Rack

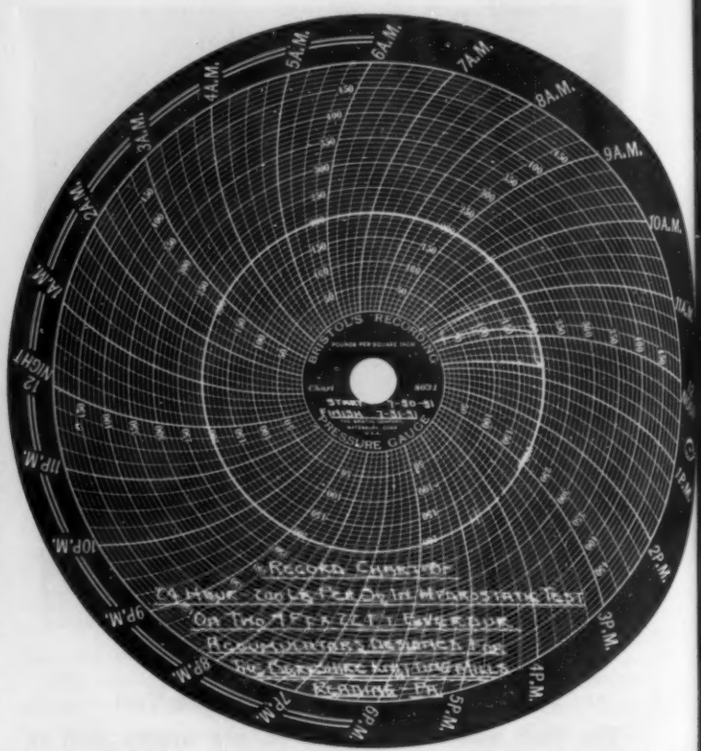



Fig. 26—Clock Face From Time Pressure Gage Used on 24 Hour Shut-Off Test. Pressure Held Consistently

### 10,000-Gal. Accumulators—Pressure Tests

Although the usual test pressure for unfired pressure vessels of this nature is 1½ times the working pressure, these accumulators were tested to twice the working pressure and that for 24 hours. In fact, this 200-lb. pressure 24-hour test was applied to the accumulators twice. Fig. 25 shows these two vessels on the test rack.

The initial application of the 200-lb. pressure which develops a stress in the shell walls of 21,600 lb. per square inch indicates that the comparatively low yield point of Everdur hot rolled plate is quickly raised by stressing the plate. The data taken at the time the pressure was applied shows that after the 200-lb. pressure had been reached, no further permanent increase in circumference was noted, thus

| Test Pressure | Time | Circumference at Center |
|---|---|---|
| 0 | 2:05 | 28′ 3″+ |
| 115 | 2:25 | 28′ 3-5/16″ |
| 200 | 2:45 | 28′ 3-5/8″ |
| 200 | 4:00 | 28′ 3-5/8+ |
| 0 | | 28′ 3-3/8″ |

After the initial test, the two large accumulators were connected together and given a 24-hour test at 200-lb. pressure. With the pump shut down and the valves closed, there was *no drop in pressure.* Fig. 26, which again indicates that the shell was carrying the load with no change in shape. This 24-hour test was repeated with the same results.

### General Conclusions

A metal having the general properties of copper has long been desired as a material for the manufacture of pressure vessels. Copper itself has been used

to a limited extent, but its use has been greatly restricted due partly to its low strength and partly to fabricating difficulties attending its use. In Everdur we have a metal which has even better corrosion resistance than copper while it approximates the strength of mild boiler steel and, as measured by elongation, it has a ductility comparable to that of Swedish iron.

We have demonstrated in the foregoing that the material is readily welded, an excellent strength and ductility being attained by the procedure outlined. Fabrication by welding methods has been proved to be a practicable and economical method of construction while the design has been simplified greatly by the use of butt-welded seams. Finally, the pressure tests, more than usually severe for vessels of this type, showed results entirely satisfactory and wholly in harmony with results obtained on test samples.

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# Welding Solves Another Problem

*By* **FRANK P. McKIBBEN***

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by Frank P. McKibben, Consulting Engineer. Cuts furnished through courtesy of the General Electric Co.

RECENTLY upon completion of the shop-riveted, field-welded, fourteen-story addition, which is the sixth section of the DuPont Company's main office building at Wilmington, Delaware, these headquarters covered an entire city block except for some interior open courts. Access to the stage entrance of the DuPont theatre consisted of a narrow passageway leading from Orange Street through the main structure to one of these interior courts; but with the completion of the sixth section, this driveway was too narrow and had to be widened.

This widening involved the removal of that portion of a main building column which extended from the street level to the first floor, leaving the balance of the column to support the roof and the twelve floors from the second to the thirteenth inclusive. The removal of a lower portion of this existing column necessitated the introduction of a double plate girder over the driveway to support the first floor, the girder's own weight, the

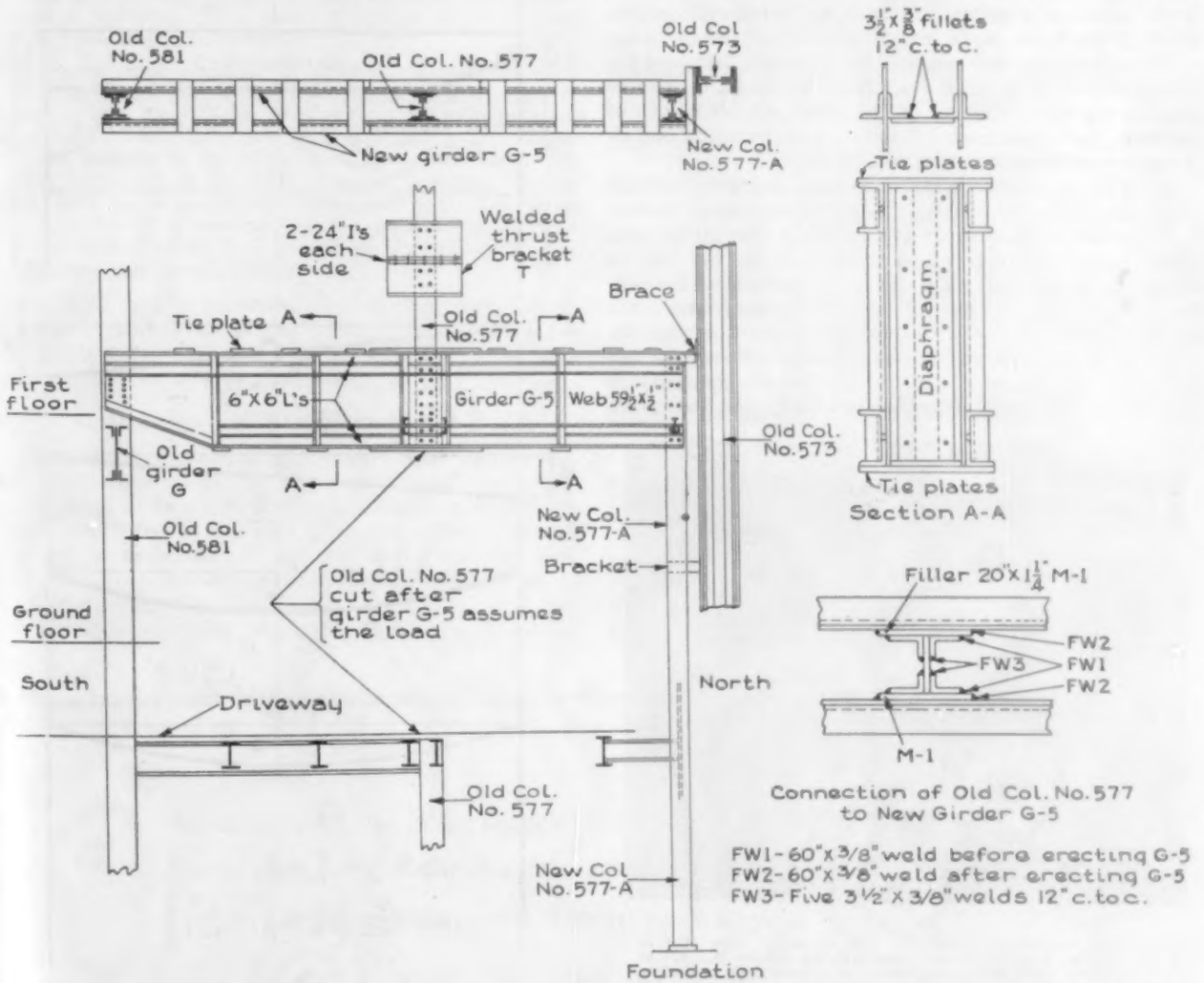


**Fig. 1**

The removal of the lower portion of a column No. 577 necessitated the use of a new column No. 577-A and a new girder G-5. The column's load of 460,000 lb. was transferred to the girder by means of two hydraulic jacks placed between thrust bearings, T, and girder. Column was arc-welded to girder, and then the lower part of column was removed with a torch

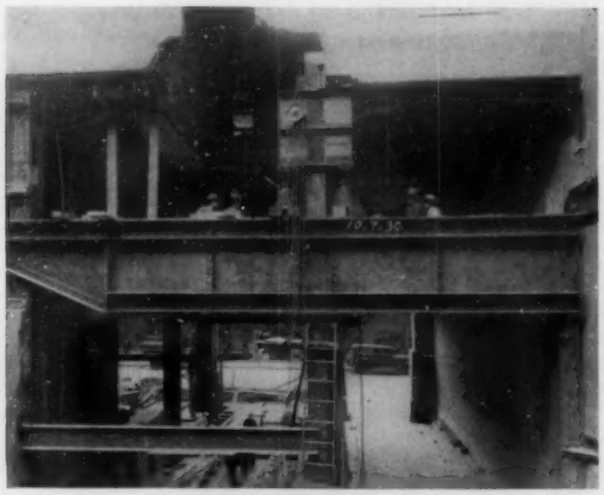

Fig. 2
Transferring a dead load of 460,000 lb. from an existing column to a new double girder at Wilmington by means of hydraulic jacks. Existing column and jacks are shown at center of girder. New column No. 577-A at right (north). Conditions existing before girder was bolted or welded to column No. 577

load transferred to it from the undercut column, as well as that part of the interior court wall directly above the girder. These changes were to be made with as little noise as possible and with no perceptible settlement of the floors, walls and other parts of the building.

Therefore, the problem, succinctly stated, involved the transference of a large load from an existing column to a new girder, removal of the lower story's length of column, the abatement of noise, and avoiding subsidence of existing construction.

In order to minimize noise, welding aided by bolting, was used in the field work. The girder was shop riveted.

To avoid settlement of the building the girder was given such a predetermined deflection by the use of hydraulic jacks that when the lower portion of the central column was cut away with the oxy-acetylene torch no subsidence in the structure above was perceptible. In other words, the girder was given in advance its full deflection by the jacks (before the column was cut) in such a manner as to transfer gradually the load from

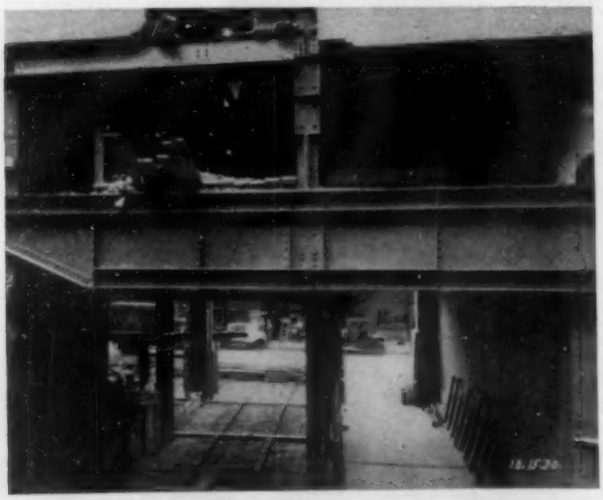

Fig. 3
Girder G-5 supporting column No. 577 at center after load of 460,000 lb. has been transferred from existing column No. 577 to girder. Girder webs have been welded to column; the projecting arms of thrust brackets T and the lower portion of column 577 have been removed by flame torch. What appears to be the old column under girder is merely a wooden post used in erection. South is at left, north at right end

column to girder, leaving undisturbed, at their original levels, the various floors, walls and other portions of the building.

The girder, consisting of two separate parts each with web and flanges so that a part could be erected on either side of the existing column, had the webs partially removed at its south end, and the lower flanges inclined to avoid interference with an existing girder, G, connecting to existing column No. 581, Fig. 1. The two parts of the girders were later connected by diaphragms between the webs, and by tie plates across the flanges.

Connections of the various floor beams to one another and to girders were made by welding or bolting in the usual manner and require no comment.

The following denotes the sequence of main events:

1. Installation of foundation for new column No. 577-A supporting north end of girder G-5; removal of masonry to permit other changes contemplated.
2. New column No. 577-A erected and braced to old column No. 573.
3. The two separate halves of girder G-5 were erected, one on either side of old column No. 577; the two parts were

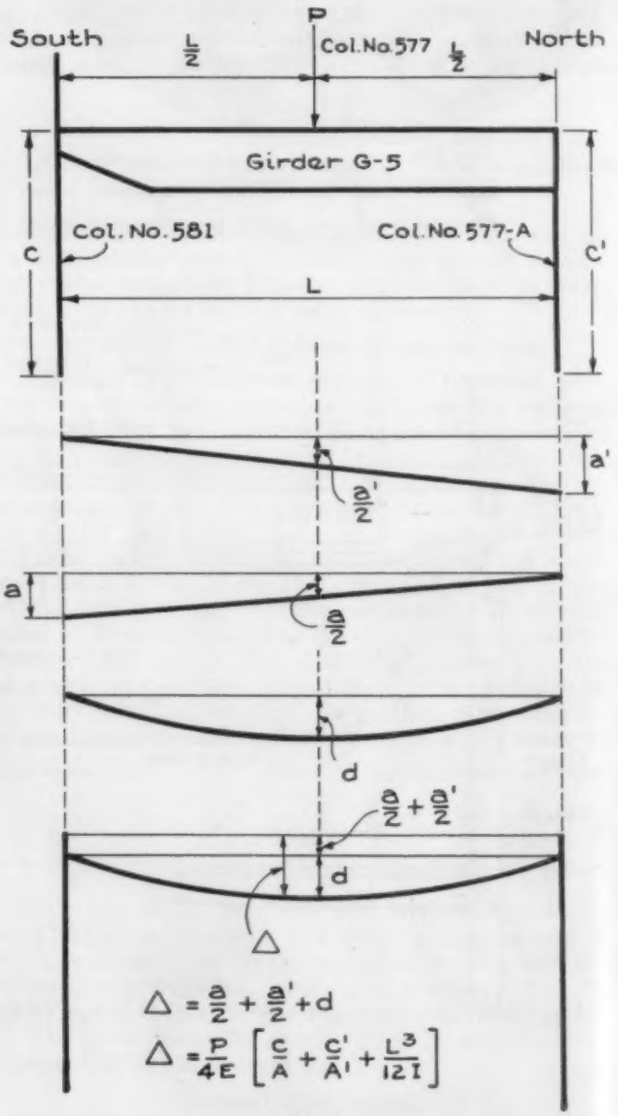


Fig. 4
Deflection at center of girder relative to the earth is composed of that due to shortening of the supporting columns, together with the girder's self-contained deflection

bolted to new column No. 577-A; girder G-5 web diaphragms and flange tie-plates bolted in place.

4. Girder G-5 leveled; holes drilled in column No. 581 to match shop holes in the girder G-5, and girder was bolted to column No. 581; new first floor framing was erected and bolted.

5. To secure initial deflection of new main girder G-5 by transferring to it the load of 460,000 lb. from the existing column No. 577, two thrust brackets, T, Fig. 1, each consisting of two 24 in. 79.9 lb. I beams, were first bolted, then welded to existing column No. 577, with a total of 192 in. of ⅜ in. fillet; after which two hydraulic jacks were inserted on top of girder G-5 and under these thrust brackets, Fig. 2. As pressures were applied to the jacks the girder deflected downward till the deflection with respect to the ground had reached the calculated amount of approximately ¼ in. Wedges were then inserted in the jacks. Two pieces of 4-inch shafting, set between the thrust brackets, T, and the top flanges of girder G-5, were tack welded in place. These precautions were taken to avoid possible motion due to leakage in the jacks.

6. Meantime, braces connecting old column No. 573 to new girder G-5 and to new column No. 577-A were welded; two fillets each of 36 in. and two of 60 in. each were placed to connect the north end of new girder G-5 to new column No. 577-A; and two fillets of 32 in., and two of 38 in. each, were laid to transfer stress from south end of girder G-5 to existing column No. 581.

   Field welds FW-1, Fig. 1, were made to connect the column angles to filler plates M-1; and FW-3 to connect these angles to column web.

7. The final steps consisted in drilling, while girder G-5 was thus under deflection, a series of holes through it and column No. 577 for the insertion of bolts to draw the two parts closely for welding; placing four fillets FW-2, each 60 in. by ⅜ in., to connect filler plate M-1 (and hence column No. 577) to girder G-5; then cutting off, with the oxy-acetylene torch, that part of existing column No. 577 extending from the driveway level to the lower side of girder G-5, as well as the projecting ends of thrust brackets T, Fig. 3.

The dead load to be transferred during construction was approximately 460,000 lb. Provision was made for a possible total live and dead of 500,000 lb. to pass from column No. 577 to girder G-5.

### Deflection of New Main Girder

The ultimate deflection of the girder at column No. 577, after removal of the lower portion of the latter, is composed of two actions: first, deflection within the girder itself due to the load from the column; second, that due to shortening of the supporting columns Nos. 581 and 577-A caused by compression transmitted to them from ends of girder G-5.

The following study illustrates these simple computations for deflection of the girder at column No. 577; Fig. 4:

$P$ = total load applied by column No. 577 to center of girder G-5 = 460,000 lb.

$A$ = gross cross-sectional area of column No. 581 = 97.5 sq. in.

$c$ = length of column No. 581 = 400 in.

$a$ = shortening of column No. 581 in inches due to compression of $\frac{P}{2}$ lb.

$A'$ = 27.05 sq. in.; $c'$ = 400 in.; for column No. 577-A.

$a'$ = shortening of column No. 577-A due to compression of $\frac{P}{2}$ lb.

$E$ = modulus of elasticity = 30,000,000.

$I$ = moment of inertia of cross section of girder (assumed constant) = 69,400 inch units.

$L$ = span of girder = 360 in.

$\Delta$ = deflection of center of girder; due to shortening of columns Nos. 581 and 577-A, and to load of $P$ at the center; = 0.286 in. as found below.

The details follow:

Deflection at center of girder due to $P = d = \frac{PL^3}{48EI}$

Shortening of column No. 581 due to compression of

$$\frac{P}{2} = a = \frac{Pc}{2AE}$$

Shortening of column No. 577-A due to compression of

$$\frac{P}{2} = a' = \frac{Pc'}{2A'E}$$

Total deflection at center of girder with respect to the earth is

$$\Delta = \frac{a}{2} + \frac{a'}{2} + \frac{PL^3}{48EI}$$

$$\Delta = \frac{Pc}{4AE} + \frac{Pc'}{4A'E} + \frac{PL^3}{48EI}$$

$$= \frac{P}{4E}\left[\frac{c}{A} + \frac{c}{A'} + \frac{L^2}{121}\right]$$

$$= \frac{460{,}000}{4\,(30{,}000{,}000)}\left[\frac{400}{97.5} + \frac{400}{27.05} + \frac{(360)^2}{12(69{,}600)}\right] = 0.286 \text{ in.}$$

The value of 0.286 in. represents the amount of initial central deflection with respect to the earth that should be given the girder.

Structural steel design by Du Pont Company's engineering department. Steel fabrication and erection by Belmont Iron Works; welding by Mellon, Taylor, Hendrickson, Inc. Carson and Carson and the writer supervised welding and inspection thereof.

Written and Oral Discussion of all Fall Meeting Papers is invited by all members of the Society. Send discussion to the Editor of the JOURNAL OF THE AMERICAN WELDING SOCIETY.

# Resistance Welding of Metal Fabric

*By* W. T. OBER

✦ This paper is to be presented before the Fall Meeting of the A. W. S., in Boston, September, 1931, by W. T. Ober, Asst. Sales Manager, Thomson-Gibb Electric Welding Co.

NO DOUBT, you are familiar with metal fabric such as window screening, sand screens, coal screens, fencing, concrete reinforcements for buildings, or concrete road reinforcements. This paper will deal only with those types of fabric made up from a number of individual steel rods or wires where the mesh is square or rectangular in shape and is made by welding each wire or rod to each wire or rod that it crosses at the points where they cross.

Before the advent of welded fabric, the process used was a form of weaving. About the largest size of wire used in any woven fabric was No. 4 gauge. Somewhat over thirty years ago, one Mr. J. C. Perry patented

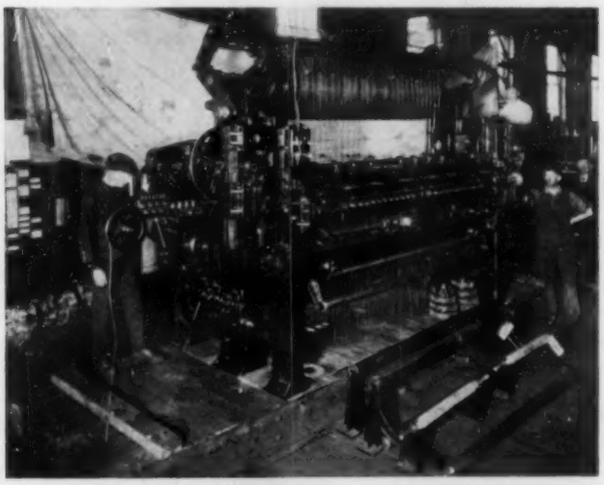

Fig. 1

equipment for the resistance welding of metal fabric and the first machine manufactured under his patents was built by the Clinton Wire Cloth Co. at Clinton, Mass. This first machine was made for wire fencing and light reinforcing, and was suitable for fabric of fairly narrow width only. As is usual with first machines, it was not a complete success, but gave promise of providing a means for turning out welded fabric. Within the next few years, a goodly number of similar machines with corrections and improvements were designed and manufactured by the Clinton Wire Cloth Co.—these later machines being capable of handling larger diameter wire and much wider fabric. It is our understanding that a machine to weld 100″wide fabric was the largest manufactured by them and that this machine was capable of welding fabric suitable for light road reinforcement. This machine, Fig. 1, is of the so-called automatic type where all of the longitudinal wires are taken from reels, threaded into the machine—these wires passing up through straightening and tension rolls, passing by the welding electrodes

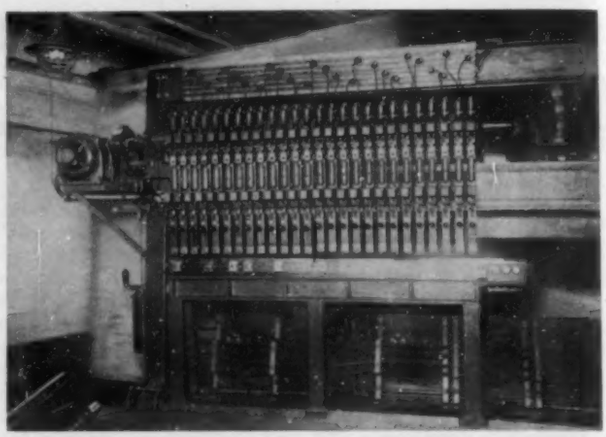

Fig. 2

in a vertical plane and thence up over take-up wheels or drum, and then to wind-up roll, which coils the completed fabric. It is not, of course, necessary to coil the fabric as the fabric leaves the machine in a flat sheet and may be taken off as such or coiled at the user's will. The transverse wires are taken from reels, fed through straightening rolls, cut to length, received by fingers which at the proper instant in the cycle of the machine, places these transverse wires into position in the welding electrodes; then the welding electrodes move forward and all of the welds between transverse wire and all longitudinal wires are made at one time after which the take-up wheel or drum automatically moves the fabric along to the next determined position for receiving a transverse wire.

Each weld is made by an individual transformer of proper rating depending upon the size of the wire to be welded. Each pair of welding electrodes, while controlled from a common drive exerts pressure at the point of the weld, independently of any other pair of electrodes by means of an adjustable spring so that in wire welding units, so arranged and operated that they make all welds simultaneously, the work being at a standstill while welding is being done. Each welding unit has its own circuit making and breaking switch adjustable to provide for setting so that welding current is not turned on until a predetermined pressure has been exerted on the work and to shut off the welding current after a predetermined movement of one electrode has sunk into the other wire a predetermined amount.

As the use of concrete road reinforcement increased

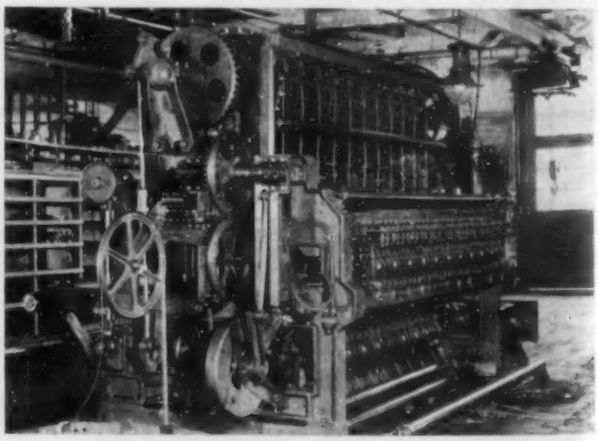

Fig. 3

and wider roads came into use, also, the loads which these roads had to carry became greater, the demand for wider sheets of fabric made from heavier rods or wires also increased. Then, too, the demand for larger sheets of heavier fabric for building construction and general reinforcement purposes increased. At first, it was felt that the automatic type of welder could not be used for making this heavier and wider fabric because of the stiffness of the rods or wires used and the great power and bulk of parts which would be required for the automatic feeding, straightening, cutting and reeling of these heavier wires. During that period, there were a number of machines of the semi-automatic type developed and built by manufacturers of welding equipment, and also manufacturers of reinforcement fabric. This particular type, Fig. 2, was designed to make a six-foot width of fabric where the maximum size of both longitudinal and transverse rods was 3/8 in. in diameter. The machine was equipped with twenty-six (26) welding heads or units, all operated from a common driven drum carrying a series of cams for actuating the welding heads. Only one welding transformer was employed—this transformer being rated at approximately 75 kva and all the welds were not made simultaneously but rather in rapid rotation. The drum carrying the cams for operating the heads rotated at a speed of approximately 12 r.p.m. or, in other words, when using the total twenty-six (26) welding heads with which the machine was equipped, all twenty-six (26) welds were made in approximately five seconds. There was provided on the machine storage space for welding heads or units not in use on the particular mesh being welded. This was to provide for making mesh employing various numbers of longitudinal wires so as to obtain different spacing of these wires. The narrowest spacing of longitudinal wires provided for was 2 in. All of the longitudinal and transverse wires were straightened and cut to length before coming to the machine. Suitable jigs and carriage were used into which the wires were loaded and then this jig and carriage moved manually through the throat of the machine to bring it into position for the welding of each successful transverse wire to longitudinal wire. The fabric thus obtained was in the form of a flat sheet.

During the next few years there was considerable interest in this flat type of fabric and numerous concerns were interested in welding fabric made from rods —the material being re-rolled railroad rails. This material, being hot rolled, having a fairly heavy coating of scale and containing a rather large amount of carbon, presented somewhat different welding problem than the fabric made from clean wire or rod of low carbon content. It is, of course, a well recognized fact that any appreciable coating of scale or rust is an insulator and interferes with the passage of low voltage, high amperage welding current. Because of the relatively high surface resistance between the two pieces of work to be joined caused by this insulating scale, somewhat heavier pressure must be exerted on the work in order to assist in preventing the burning of the material at the highly localized points of initial contact. Also, in the case of this high carbon content material, if the weld is made very quickly, say in a fraction of a second, very little material outside of the weld zone becomes heated to any degree, and therefore, the welding joint will cool rapidly in the air, resulting in brittleness. It is obvious that if a low enough open circuit secondary or welding voltage across the electrodes is used so that in the case of clean wire, the welding time would be several seconds, this welding voltage will not be sufficient to break through the coating of scale in many cases, and if it does, there is also danger of burning the material at the weld and of one wire sinking into the other to too great a depth, thus destroying the strength of the joint. It has been accepted by most manufacturers of welded fabric that the total added thickness of the two wires at the completion of the weld should not be less than *approximately two-thirds* the total thickness of the two unwelded wires if maximum strength is to be obtained. The above refers, of course, to round wires or rods.

One scheme which has been employed successfully in the welding of this scaly high carbon content rod is to employ what we term bridge-type electrodes; that is the electrodes do not contact with the wire directly over the point of weld, but rather at two points on each wire, approximately one to one and one-half diameters away from the center line of weld. In this way, not only is the material at the weld heated, but also, the material for some distance either side of the weld, thus insuring sufficient heat remaining in the weld for a long enough period of time to obtain a partial anneal. Fabric welded in this manner has withstood successfully the usual tests to which such fabric is submitted. Because of the extreme stiffness of these rods made from re-rolled rails and the coating of scale, they have not, as yet, been successfully welded on the automatic type of equipment employing the automatic feeding from reels, straightening, and cutting-off devices.

Figure 3 shows a recent, full-automatic fabric welder, designed to accommodate fabric 102 in. in width, or 100 in. between the center line of outside longitudinal wires with provision for a 1 in. overhang on each side of each transverse wire, all wires being clean and of low carbon content.

This particular machine is equipped with thirty-one (31) welding transformers and welding units, thus making it suitable for accommodating maximum of thirty-one (31) longitudinal wires, minimum spacing of which is 2 in. These spacings may be increased in steps of ½ in. by adjustment provided for each welding unit and transformer. When the width of mesh becomes any even multiple of 2 in., it is, of course, only necessary to break the primary circuit of the intermediate welding transformers and remove the welding electrodes from the same units, in order to make these intermediate units inoperative and thus obtain the desired spacing.

The minimum spacing of transverse wires is 2 in. and this spacing may be varied in steps of 1 in. up to 16 in. with the exception of 13 in. and 15 in., which are not obtainable because of the design of the double pawl and ratchet, and ratchet wheel used for rotating the take-up wheel or drum. These spacings of 13 in. or 15 in. are ones, however, which to date, have never been encountered or desired.

The total transformer capacity of the machine is approximately 360 k.v.a. and the electrical connections are so made that the thirty-one (31) transformers are divided between the phases of a three phase circuit, there being ten each on two phases and eleven on the third phase. This gives a very nearly balanced load on the three phase circuit and connections are so provided and made that this balance may be practically maintained regardless of the number of transformers or units being used on any particular fabric. One motor is used for driving of all mechanical parts and when the large number of necessary movements and the

timing of these movements is considered, you will agree that the successful co-relation of all of these operations and movements is a feat from which the designer should derive considerable satisfaction.

A machine of this type will weld fabric with longitudinal wires from approximately No. 14 to No. 0 and with transverse wires up to approximately ¼ in. in diameter. Another similar machine is capable of handling mesh up to 124 in. in width with maximum diameter of longitudinal wires ⅜ in., minimum diameter approximately 0.135 in. and transverse wires up to 5/16 in. in diameter. This particular machine is equipped with thirty-two (32) transformers and has a total rated transformer capacity of 750 k.v.a. This machine is equipped to automatically feed and straighten all longitudinal wires from reels and feed, straighten and cut all transverse wires up to approximately ¼ in. in diameter. When larger diameter transverse wires are used, an automatic magazine feed is employed which receives pre-straightened and pre-cut lengths of wire. Same variation in mesh sizes may be obtained on this machine as on machine just described. To give you an idea of the production which may be obtained, either of the above machines may be operated at speeds as high as 30 or even 35 cycles per minute; that is, 30 or 35 transverse wires welded to all the longitudinal wires per minute—this being on fabric for 9 and 10 ft. road reinforcement. The tonnage which may be obtained for a given period of operation depends largely, of course, not only on the speed of operation of the machine, but also, on the number of longitudinal wires employed in the fabric being welded and the spacing of the transverse wires. Obviously, the longitudinal wires generally being larger in diameter than the transverse wires, the more longitudinal wires which are used and within reasonable limits, the greater the spacing of the transverse wires up, say to 12 in., the greater the tonnage obtained for a given speed of operation of the machine and high speed operation may be used readily with 12 in. spacing of transverse wires.

Oft-times, an inquiry for a fabric welding machine will specify a fairly narrow width and of course, a machine to accommodate only a narrow width which is generally made of fairly small wires, is somewhat less expensive than a machine to handle twice this specified width. However, anyone considering fabric welding equipment should anticipate his future requirements and if finances permit at that time install a machine capable of handling not less than 100 in. width, as these machines may be equipped and in fact have been equipped with automatic slitting devices which slits the wide fabric into two narrower strips of fabric so that the production obtained from a wider machine can be double that obtained from narrower machine and the use of the wider machine permits the manufacture of fabric such as is used in road work and for which the demand is constantly increasing. Machines may be supplied which would permit not only making a double width of fabric but a triple width and the initial cost of a machine accommodating say a 100 in. wide fabric is not twice that of a 50 in. or 60 in. width machine. This applies particularly where the inquirer wishes to use a narrow machine for fabric made from the larger wires such as No. 0 and No. 000 as well as the small wires used in fencing and light construction work. The field for this metal fabric is constantly increasing and the demand for machines of the automatic type for fabric up to 12 ft. and even 14 ft. has already arisen and the next few years will, no doubt, see several of these larger machines installed.

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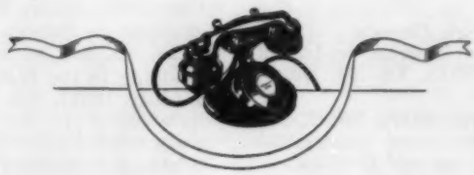

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